

## THE SIGNIFICANCE OF HEALTH SELECTION AMONG DIVERS AND ITS EFFECT ON DIVING SAFETY

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### ABSTRACT

Diving is a kind of human activity that requires special health predispositions due to the nature of an aquatic environment. The environment of an increased atmospheric pressure imposes a significantly greater burden on the respiratory and circulatory system as compared with normobaric conditions. Due to their health status, not everyone among those that wish to take up diving should undergo diving training, as diving can have an adverse effect on their condition while staying under water and considerably raise the risk of an occurrence of a diving accident. As regards diving activities performed within the Armed Forces, individuals with particular health burdens are eliminated via the medical checks conducted at the time of recruitment to the diving service. The checks, based on detailed parameters and described in legal acts, minimise the risk of an occurrence of a diving accident. This problem is quite different when it comes to recreational diving, where quite often, by presenting a health certificate, an interested diver candidate begins a training course and further individual diving activities while being aware of a medical condition that may affect their future safety under water. An analysis of the effect of health selection on the level of diving safety was performed.

**Key words:** health selection, medical assessment, health burden.

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## INTRODUCTION

Long-term own observations of the authors related to diving safety in dives performed for military and recreational purposes enabled to verify the significance of health selection among diving candidates and active divers, both military and recreational. Both forms, i.e. dives performed for the purposes of the Armed Forces as well as recreational diving, impose identical physiological requirements with regard to the effects of an increased pressure on the human organism, however demonstrate a substantially different approach in relation to the health conditions that a diver needs to meet to ensure safety of the diving process.

The fundamental step that allows for the elimination of candidates to the diving service consists in medical certification which has an influence on the entire course of the diver's service from the moment of his/her qualification through annual certification for service based on comprehensive diagnostics enabling monitoring of the health effects of work in hyperbaric conditions. Along with psychological tests, qualification for service subject to strict health regimes and procedures is conducted, as the discussed type of service is particularly difficult due to the working environment, physiological limitations, psychophysical burden and the risk resulting from the impacts of this natural environment.

Legal acts regulating health norms for candidates and divers remaining in active service define the health criteria, eliminating those health burdens that have a negative effect on the divers' safety level; it is recognised that the status of the divers' health is often the cause of adverse events linked to diving incidents ending in death. Recreational divers, on the other hand, are not required to be subject to a health qualification to perform diving activities.

The absence of regulations or specified health requirements for recreational divers, means anyone who expresses a willingness to undertake a dive, can do so – irrespective of their health status, and despite the fact that the recognised or unknown health burdens of a recreational diver elevate the risk of a diving accident (or may even pose a threat to their his/her health or life). A lack of health checks in the environment of recreational divers is reflected in considerably more frequent diving accidents having serious health effects.

Social and economic transformations have resulted in an increased availability of diving equipment in civil environments, which in turn has resulted in the development and enhanced popularity of recreational diving as a generally available sports activity for individuals of all ages.

The absence of health checks, insufficient knowledge of human pathophysiology and, at times, a complete lack of diving training, has been highlighted in the circles of recreational divers on multiple occasions by much more numerous diving accidents as compared to the statistics of the Armed Forces, including the fatal ones.

The objective of the work was to perform an evaluation of health selection among candidates for divers of the Armed Forces and recreational divers from the United States and Canada, who were not subject to standardised health selection in the years 2002 – 2007.

## MATERIAL – CHARACTERISATION OF THE RESEARCHED GROUPS

Impact assessment of the health selection of divers of the Diver Training Centre of the Polish Army in Gdynia in the years 2002 – 2007 was carried out on the basis of the data contained in the Diver Activity Logbook, results of medical statements of the Military Maritime-Medical Commission temporarily limiting the soldiers' diving capability due to health reasons in the researched group and documentation concerning diving incidents among members of the researched group. The study involved 20592 hyperbaric exposures, including dives performed in open bodies of water, diving pools, exposures performed in decompression chambers and oxygen tolerance tests also performed in decompression chambers. The research encompassed 1169 divers.

The comparative analysis was based on data concerning recreational divers from the United States and Canada that were not subject to health selection qualifying for diving, a group of 8964 recreational divers who performed the total of 115479 dives. The output data were contained in Diving Alert Network Reports from the years 2002 – 2007.

## METHODS

A retrospective research based on publications and source documents.

Due to the specificity of the diving service, candidates should be characterised by a good general physical fitness and a very good health status. Before determination of service capability each candidate underwent initial psychological assessments, specialist medical examinations and laboratory analyses and imaging tests required by relevant provisions. In concord with the regulations of the Minister of National Defence governing the diver certification process is carried out by competent Military Medical Commissions.

Candidates to the diving service were first of all subjected to psychological tests. After obtaining a positive psychological evaluation medical examinations were continued until the decision of the Military Maritime-Medical Commission confirming the diver's capability to perform military service as a diver.

Psychological assessments of candidates were carried out by the Psychological Laboratory of the Navy for the purposes of the Military Maritime-Medical Commission.

Psychological examination encompassed 3 phases:

1. filling in of a psychological interview form by an examined person containing – besides basic personal data – questions concerning education, family status, profession, completed schools, educational difficulties, past head injuries, psychological and somatic conditions, used medication, use of psychoactive substances or alcohol.

2. estimated determination of the level of intellectual development on the basis of the so-called J.C. Raven matrices test;

3. personality examination with the use of the so-called Personality Inventory (MPI) of H.J. Eysenck. Personality was defined with regard to two basic dimensions:

- neurotism level;

- introversion and extroversion level,

\* examination of the so-called lie scale serving the determination of the level of truthfulness of a subject.

4. anxiety level testing as a personality characteristic with the use of a test constituting an adaptation of an American test called State-Trait Anxiety Inventory (STAI). Following screening tests, in the second phase each candidate to the diving service had an individual consultation with a psychologist – specialist within clinical psychology. On the basis of the conversation and the thus far conducted tests, the psychologist – in case of doubts regarding the correctness of functioning of the subject's psychic sphere – qualified the subject to further testing.

The last element of psychological evaluation consisted in the determination of the following:

- intellectual development level with the use of WEIS-RPL test;

- possible organic changes in the central nervous system constituting the reason for behavioural disorders with the use of A. L. Benton's Visual Retention Test and the Graham-Kendall Memory-for-designs test; these tests allow detection of disorders of eye-motor coordination, concentration and attention, recent memory, constituting symptoms of organic changes of the CNS.

In the case of behavioural disorders caused by pathological personality features the psychologist formulated the final diagnosis on the basis of the psychological interview sheet, personality test results, consultation and candidate observation in the course of testing. A positive result of the psychological test constituted an absolute pre-condition to obtaining certification to perform the diving service at sea.

Specialist medical examinations included:

1. Internal examination with particular attention to possible conditions of the respiratory, circulatory or alimentary system, evaluation of electrocardiograph examination;

2. Surgical examination with particular emphasis on the condition of the motor system, presence of distortions in body build, scars, past surgical treatments, presence of varices;

3. Ophthalmological examination evaluating visual acuity in the subjects, ability to discriminate between colours, examination of the bottom of the eye and lens transparency;

4. Otolaryngological examination with evaluation of the condition of the organ of hearing, paranasal sinuses, tympanic membranes, presence of chronic inflammations in the area of the nasopharynx and Eustachian tubes;

5. Neurological examination aimed at the detection of any abnormalities in the functions of the central nervous system and peripheral nerves;

6. Dermatological examination to detect any acute and chronic conditions of body integuments;

7. Dental examination necessary for the determination of the condition of the dentition in the subjects, lack of masticatory surfaces, occurrence of caries and chronic conditions of the paradontium;

8. Psychiatric examination for the presence of psychiatric disorders, personality disorders, emotional instability, character disorders, etc.

Additional testing encompassed:

1. Radiological examination of the chest,

forehead and paranasal sinuses, radiological examination of heads of long bones;

2. Electrocardiograph examination, echocardiograph examination;

3. Audiometric examination;

4. Electroencephalograph examination;

5. Laboratory tests: blood morphology with smear and OB, general urine analysis, glucose, urea, creatinine, bilirubin and transaminase concentrations in the blood serum, as well as presence of viral hepatitis B and C antigens.

Sporadically, depending on particular specialist doctor's recommendations other tests were performed (lumbar-sacral spine X-ray, sector of vision assessment in the case of suspected glaucoma, electrocardiographic exercise test, computed tomography and magnetic resonance). In particularly difficult cases the subjects were referred for hospital observation performed at the 7th Naval Hospital in Gdańsk-Oliwa.

On the basis of the received medical, psychological and additional examinations, the Military Maritime-Medical Commission composed of three officer-doctors issued a certificate on the capability of a particular individual to perform military service as a diver. The certificate included the following:

- medical diagnosis constituting the basis for the determination of the subject's health category;

- determination of the category of capability to perform a particular type of service;

- detailed justification of the decision;

- instruction on the appeal procedure to the content of the medical statement.

The Armed Forces of the Republic of Poland have strict regulations regarding the health status of diver candidates, supported by diver health monitoring –an activity that starts with the diving supervisor, and continues through to the physician securing the activities of troops, including military divers, based on several legal acts issued by the Minister of National Defence and aimed to ensure the safety of all types of underwater works and training implemented by the Ministry.

The said acts include:

1. Regulation of the Minister of National Defence as of 25 June 2004, J.L. 2004 no. 151 it. 1595 regarding determination of capability to perform active military service and the related proceedings of military medical commissions [8].

2. Regulation of the Minister of National Defence as of 3 June 2015 on the determination of capability to perform military service and the properties and proceedings of military medical commissions regarding these matters, J.L. 2015 it. 761 [9]; which defines the following:

- 1) the list of diseases or disabilities considered in the determination of the capability to perform service in particular types of the Armed Forces of the Republic of Poland and armies, as well as in particular official positions requiring specific health predispositions;

- 2) the list of diseases or disabilities considered in the determination of the capability to perform service in particular types of the Armed Forces of the Republic of Poland and armies, as well as in particular official positions;

- 3) competence and modes of proceeding of military medical commissions;



4) mode of referring professional soldiers and candidates for professional military service to military medical commissions;

5) detailed conditions for the determination of capability to perform professional military service;

6) detailed conditions for the determination of limited capability to perform professional military service.

Safety principles and health selection rules regarding civil recreational diving in Poland are based on Regulation of the Minister of Sport of 17 August 2006, J.L. No. 154 it 1103 on safety principles in performing diving activities [10], which, among other things, define what follows:

1. in Sec. 3.1. "Diving activities can be performed by an individual whose health status enables their implementation in accordance with the diving plan" – this concerns organised dives, conducted by individuals with proper authorisations, whereas the health selection criterion does not regard individual and non-organised dives,

2. "Should it be required to document the health status of an individual intending to perform diving activities, depending on the needs, such an individual should present the following:

1) certificate including a medical statement on the lack of contraindications to perform diving activities or

2) statement that the individual's health status allows for the performance of diving activities".

- the requirement of conducting health selection in recreational diving is limited solely to organised dives and can be based on the statement of an interested party as to the sufficient condition of health, which may be based merely on the individual's conviction of his/her good health status, i.e. a subjective opinion, contrary to what takes place in the selection of candidates for divers and active divers on duty, supported by an objective statement on the health status on the basis of legally defined examination and determination conditions.

A similar approach is applied in the context of amateur-diver health qualifications in the majority of countries in the world.

The main advantage that results from conducting health selection among candidates for divers and active divers in the Armed Forces of the Republic of Poland is a reduction of the adverse effect of a bad health condition on the safety of performance of underwater works and training in the Polish Army.

Long-term experience has shown that striving towards the elimination of the health factor as the cause, or one of the causes of diving accidents in the defined time perspective and the number of conducted dives constitutes the fundamental condition for ensuring soldiers' safety. Monitoring of the divers' health status and their capability to perform diving within the legal frameworks defined by regulations of the Ministry of National Defence, minimises the risk related to changes in divers' health during the entire period of service and enables application of proper therapeutic procedures and return to service in the case of deterioration in health.

Apart from the doubtless benefits of health selection there are also specific limitations including the necessity to conduct examinations on a large number of candidates and selecting a group required by the Armed Forces, which is also expressed in the economic dimension.

A properly conducted medical examination for the purpose of determining the subject's capability to perform diving activities followed by proper counselling may result in the extension of diving safety [1].

In order to depict the effect of health selection *wystąpienia pogorszenia stanu zdrowia*. on diving safety, a correlation analysis between particular health conditions and the risk of an accident occurrence was carried out.

The group of adverse causes having an immediate effect on the incidence of diving accidents among recreational divers includes infections of upper respiratory tract occurring directly before dive performance. Considering the nature of this group of health conditions which includes rhinitis, throat and tonsils infections – both viral and bacterial, they are always accompanied by impaired ventilation, hypersensitivity of the mucosa of the nose and throat, excessive mucus production, sneezing, cough caused by irritation of the pharyngeal mucosa. Disorders of the upper respiratory tract may lead to spontaneous choking and even drowning, which constitutes a high increase in the risk of an occurrence of a diving accident.

Due to the binding procedure in the Polish Army requiring the conduction of a medical interview and, if necessary, a medical examination immediately prior to dive performance, the divers of the Armed Forces are not allowed to carry out underwater works in the event of infections of the upper respiratory tract being detected, at least not until complete recovery, thus the correlation between such infections and the risk of a diving accident does not exist.

Infections of the upper respiratory airways occurring immediately before diving activities cause an increase in the risk coefficient of an occurrence of a diving accident in recreational divers – Fig. 1.

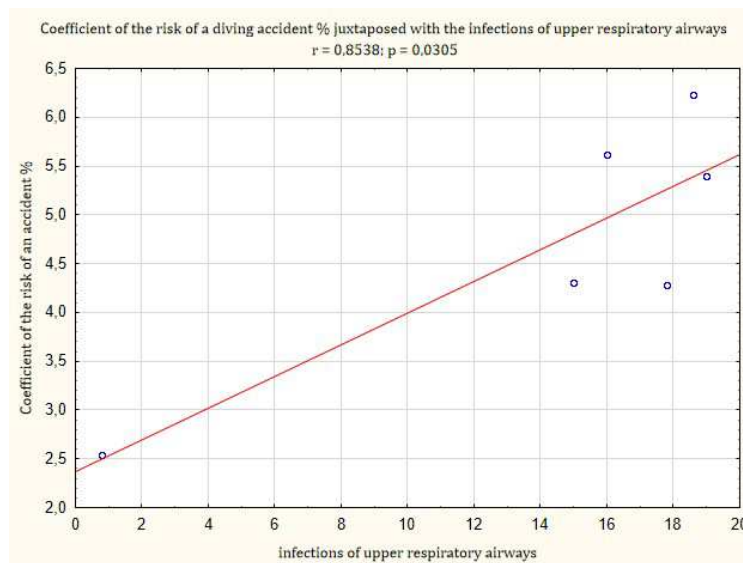


Fig 1. Coefficient of the risk of an occurrence of a diving accident among recreational divers with infections of upper respiratory tract present immediately prior to diving performance.

With significance level at  $p=0.03$ , the correlation coefficient "r" between the number of individuals with infections of upper respiratory tract in recreational divers (in the considered data this concerns infections detected immediately prior to dive performance) and the coefficient of the risk of a diving accident amounts to  $r=0.854$  and can be defined as a very strong correlation. The positive value of "r" demonstrates an increase in the accident rate along with an increase of the number of subjects with infections present immediately before diving.

A fit of bronchial asthma or an occurrence of any form of obstructive pulmonary disease causes impairment in the ventilation, hypoxia and a greater reduction of organism functions in normobaric conditions. However each obstruction intensification may have a very dramatic course, in hyperbaric conditions, with an increased burden of the respiratory system the growth of the risk of an occurrence of an adverse incident during diving is highly significant. Bronchial asthma has an immediate effect on an increase of the accident risk rate.

And this is not the only condition of the respiratory system that is considered a contraindication to performing diving activities. The absolute contraindications include:

- chronic inflammations,
- chest injuries,
- fibrosis processes of pulmonary tissue,
- sarcoidosis and tuberculosis,
- pleurisy with adhesions,
- spontaneous pneumothorax,
- exacerbated or severe bronchial asthma,
- exercise induced asthma (EIA),
- tumours and cysts located in the chest.

Relative contraindications include past surgeries on the chest and allergic rhinitis. While qualifying an asthmatic for diving it is necessary to consider his general health status, accompanying diseases, and, first of all, the asthma exacerbating factor. The treatment of a patient

allergic to an allergen that does not occur in the diving area is different to that regarding an individual with exercise induced asthma confirmed by spirometry. Despite the fact that diving with bronchial asthma is possible, it still requires great caution and prudence to ensure the highest safety during the diver's stay under water. Fig. 2.

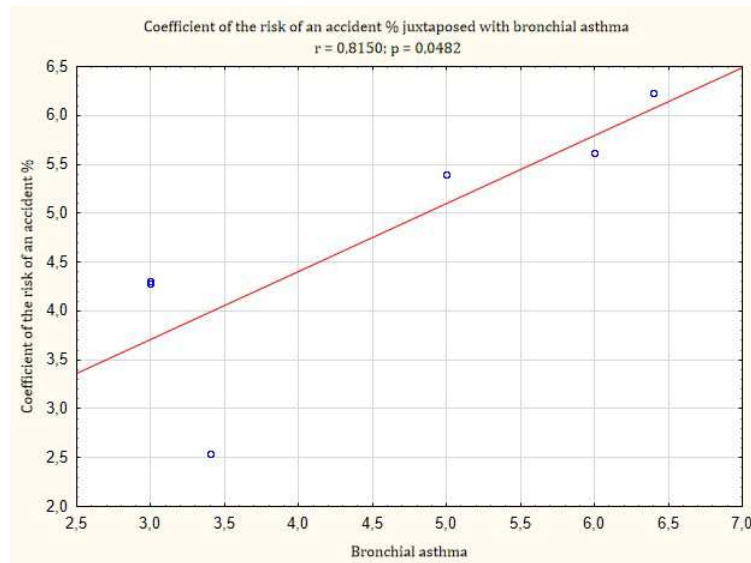


Fig. 2. Coefficient of the risk of an accident among recreational divers with bronchial asthma.

Significance level  $p=0.048$  is close to the limit value considered to be statistically significant ( $p=0.05$ ). The correlation coefficient "r" between the number of individuals with bronchial asthma (*in the considered data this concerns conditions detected immediately prior to dive performance*) and the risk of a diving accident amounts to  $r=0.815$  and can be defined as a very strong correlation. The positive value of "r" demonstrates an increase in the accident rate along with an increase in the number of subjects with infections present immediately before diving.

Recreational divers, despite the realised hazards resulting from their health situation take the risk of staying in a hyperbaric environment where they are subject to much greater burdens, particularly those relating to the circulatory and respiratory system [2].

Individuals with uncontrolled asthma, in whom the symptoms following medication persist for a period of 48 hours prior to diving activities, should not take up diving [3].

Figure 3 presents a summarised chart of health burdens in recreational divers, which could be the cause of a permanent or temporary incapacity to perform diving activities in the case of their occurrence in military divers – according to health standards observed by the Armed Forces of the Republic of Poland and the sum of incapacity to perform dives by OSN and P WP divers resulting from the decisions of the Military Maritime Medical Commission, on the basis of which soldiers were permanently or temporarily removed from diving sections.

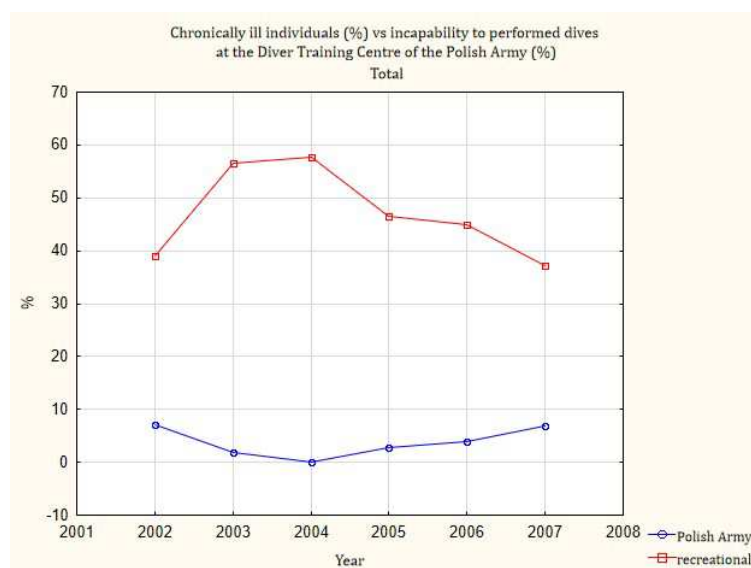


Fig. 3. Chronic neurological burdens of recreational divers and temporary or permanent incapacity of military divers to perform diving activities on the basis of the decisions of MMMC in the researched period.

The graph clearly depicts a relatively low percentage of an occurrence of temporary or permanent incapacity to perform dives due to health reasons among military divers, and a very high percentage of health burdens among recreational divers that would result in an incapacity to perform dives among military divers if as such occurred in them.

Reports confirm a more frequent occurrence of DCS of the inner ear when a patent foramen ovale is present [4]. The most frequent laryngological burdens occurring in recreational divers concern common nasopharyngeal inflammations with the occupation of Eustachian tubes and labyrinth disorders, manifested with sea sickness symptoms in the case of diving from pontoons or small boats sensitive to waves.

The frequently reported inconvenience coming in the form of sea sickness disturbs the diver's concentration, orientation under water, causes focusing on the discomfort due to symptoms instead of buoyancy, breathing, depth and consumption of the breathing mix, and, most importantly, violates the sense of time, which is the main regulator in conducting decompression.

Figure 4 depicts the level of laryngological burdens in recreational divers and the level of an occurrence of laryngological disorders in the divers of the Diver Training Centre of the Polish Army, which led to a temporary or permanent removal from diving service

according to the decision taken by the Military Maritime-Medical Commission.

Contrary to what was the case with recreational divers, the fact of removing military divers from service caused them not to create the threat of an occurrence of a diving accident. Recreational divers, despite being aware of their laryngological burdens would still conduct dives, which resulted in an increased risk of an occurrence of a diving accident and a direct reduction of the level of diving safety.

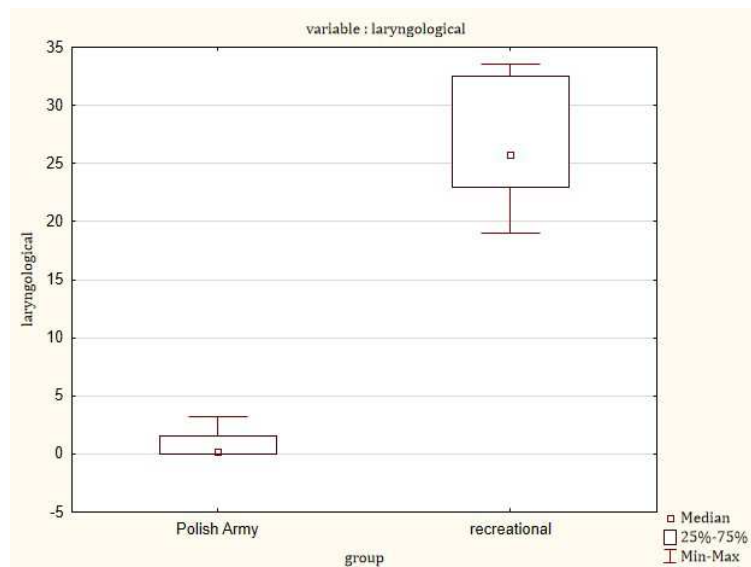


Fig. 4. The presence of laryngological burdens in recreational and military divers.

At the significance level of  $p=0.004772$  (test value  $Z=-2.82205$ ) there is a statistically significant difference between the group of recreational divers with chronic laryngological conditions and divers of the Polish Army temporarily incapable of performing dives due to laryngological disorders.

The percentage of recreational divers with laryngological conditions is statistically significantly higher than the percentage of divers temporarily incapable of performing dives due to this type of disorders. Fig. 5.

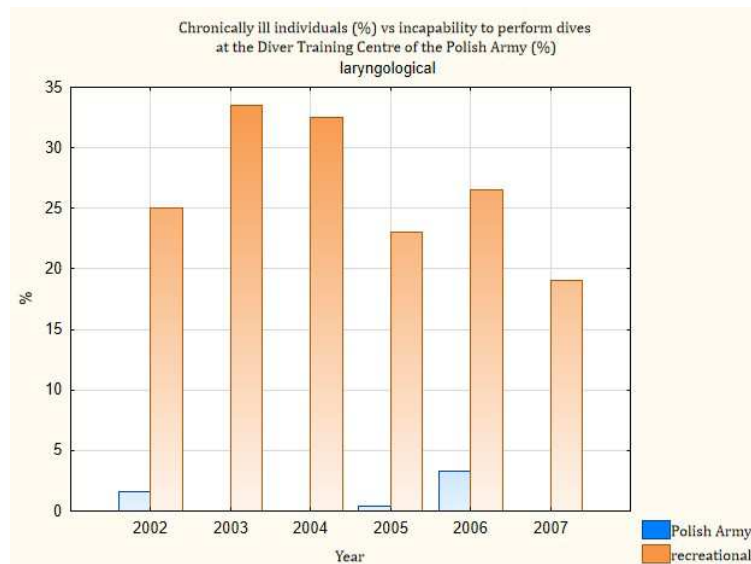


Fig. 5. Recreational divers with chronic laryngological conditions juxtaposed with the incapacity to perform dives due to laryngological causes at the Diver Training Centre of the Polish Army.

A particular group of divers is that characterised by cardiological burdens. In the case of laryngological disorders many symptoms are visible at first sight and the assessment of the risk is fairly simple, and so is the decision on aborting diving activities. When it comes to cardiological conditions, the symptoms are not manifested in an explicit way or cardiological syndromes reveal themselves only at the worst possible moments, i.e. during diving.

The most common cardiological burden consists in arterial hypertension, which is the source of changes in the circulatory system leading to its failure or even to sudden cardiac death. Health selection and monitoring of military divers' health status eliminates potential risks resulting from progressing dysfunction of the circulatory system, and, what follows, reduces the risk of a threat due to circulatory system diseases in the course of diving.

In recreational diving, which lacks health checks, the hazard related to the effect of circulatory system diseases is very high. Starting with undiagnosed somatic defects of the circulatory system, through dysfunctions of the cardiac conduction system, undiagnosed and untreated arterial hypertension to various types of coronary syndromes and impairment and an occurrence of PFO (Patent Foramen Ovale), whose presence not only have an influence on the haemodynamics of the circulatory system but also on the course and occurrence of various diseases accompanying decompression sickness, all of this equates to the risk of an occurrence of an adverse event in recreational diving or even a fatal accident as being extremely high.

Cardiological disorders in the form of a symptomatic coronary heart disease and symptomatic cardiac rhythm disturbances exclude candidates from diving [5]. Another significant factor is age. Diving for

military purposes is the domain of males, rarely of females, aged between 20-45 years.

In recreational diving this ranges is definitely broader, i.e. within 15-70 years, with the older divers aged above 50 have naturally developed burdens, for instance, in the form of arterial hypertension, progressing sclerosis, reduced effort tolerance, reduced adaptation to burdens. Cardiac-vascular syndromes are the cause of 20 to 30 per cent of all deaths that occur during diving [6]. The scale of cardiological burdens is depicted in figures 6 and 7.



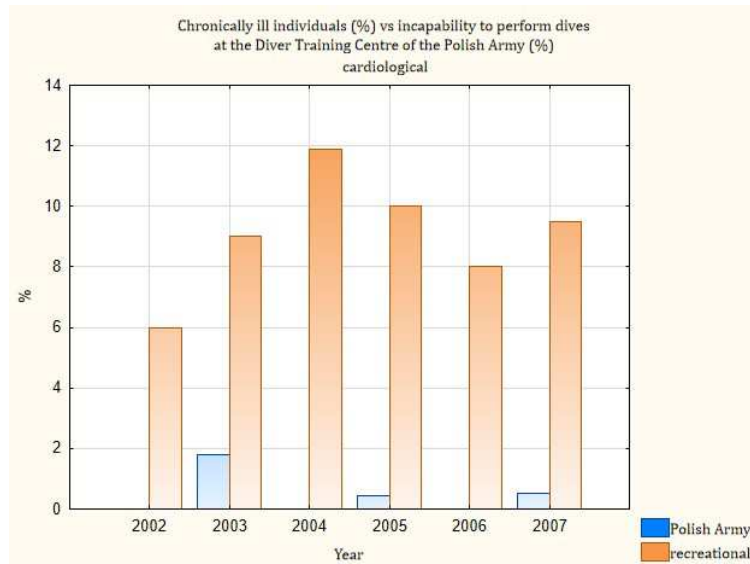


Fig. 6. Quantitative comparison of cardiological burdens noted among recreational divers and the incapacity to perform dives by military divers in particular years of the researched period.

The graph shows the difference in cardiological burdens of recreational and military divers. The main burden concerning military divers consisted in arterial hypertension manifested in divers above the age of 35 years and isolated cases of coronary syndromes.

All permanent cardiological burdens resulted in permanent removal from the diving service pursuant to the decision of the medical committee, which eliminated the cause of a diving accident and did not have an effect on diving safety. Among recreational divers, on the other hand, cardiological burdens determined the risk of an occurrence of a diving incident, including fatal accidents.

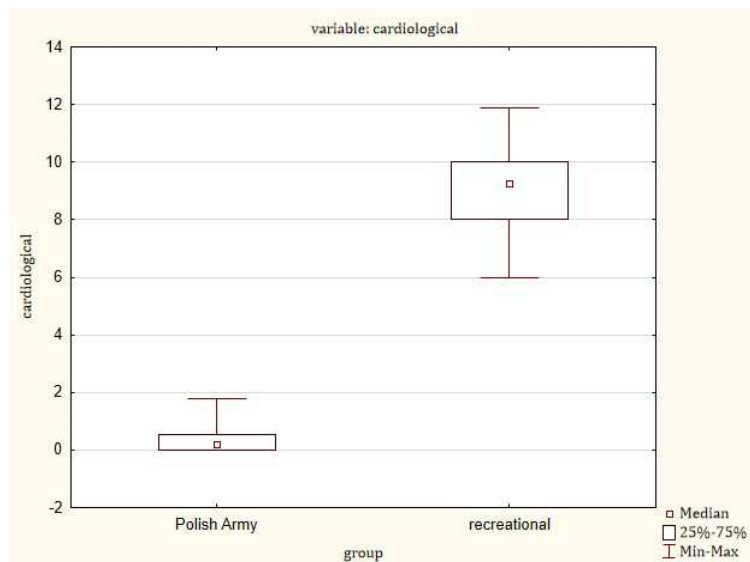


Fig. 7. The presence of cardiological burdens in recreational and military divers.



At the significance level of  $p=0.004772$  (test value  $Z=-2.82205$ ) there is a statistically significant correlation with cardiological disorders. The percentage of recreational divers with cardiological disorders is statistically significantly higher than the percentage of deferred military soldiers due to this cause.

## CONCLUSIONS

Health burdens in divers clearly elevate the risk of an occurrence of a diving accident both among military and recreational divers.

Health selection, health status monitoring and strict observance of procedures related to working under water minimises possible causes of diving accidents.

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