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Risk factors of decompression sickness in scuba diving

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The authors declare that they have no conflict of interest.

Abstract

Background

Recreational diving with aqualung can be called an extreme sport because the divers are exposed to physical and psychological risks. A serious danger in diving is the very exposure to a change in pressure underwater, which every diver must deal with. That kind of danger may cause many problems related to any pressure exposure and unfortunately, diving-related illnesses have shown the increasing tendency. Recreational divers are the most numerous group among the people who suffer from decompression sickness (DCS) and alas, similar

condition can be expected in future years. Aim of this literature review was to determine the risk factors of decompression sickness after scuba diving.

Materials and methods

Material for this literature review was found by two independent authors searching PubMed, Cochrane library and ScienceDirect databases by using a combination of keywords: „scuba diving", „risk factors", „decompression sickness", „DCS". Finally, 4 publications qualified for a review of literature.

Results

Many authors presented factors such as patent foramen ovale, BMI and fat mass, age, diving exposure, heavy exercise, sex, strong current, workload during diving, circulatory right-to-left shunt and the lack of changes in the diving style to have an impact on developing DCS. In the opposite, one study stated that overweight and gender had minor contribution to DSC.

Conclusions

Risk factors of decompression sickness in scuba diving could be: high-grade PFO, age, diving exposure, strong current, heavy exercise, workload during diving, dehydration, repetitive diving, violation of dive profiles, experience in diving, presence of circulatory right-to-left shunt and the lack of changes in the diving style after previous DCS episode. Further research is needed to verify the role of gender and fat mass in developing symptoms of decompression sickness.

Key words: decompression sickness; scuba diving; risk factors; DCS; extreme sports

Background

Recreational sports with a high dose of risk are popularly referred to as extreme sports and are associated with high chances of injury or grave danger due to accidents as the result of participating in this kind of activities. Examples of extreme sports are not only air and land-based sports such as bungee, motocross, snowboarding, rock climbing, but also underwater activities mainly including SCUBA diving (1).Self-compressed underwater breathing apparatus (SCUBA) diving has become an increasingly popular sport and passion. The number of certified divers reaches 9 million in the United States alone. Also, about 7 million divers are active and practising worldwide and every year 500,000 more are trained to become one (2,3). Recreational diving with aqualung can be called an extreme sport because the divers are exposed to physical and psychological risks. The definition of recreational scuba is explained as diving for pleasure purposes to a depth of up to 18 meters without decompression stops during the ascent (4).

Just like in any other sports, some of the health-related risks can be significantly limited and others cannot be eliminated. A serious danger in diving is the very exposure to a change in pressure underwater, which every diver must deal with. That kind of danger may cause many problems related to any pressure exposure and unfortunately, diving-related illnesses have shown the increasing tendency, having regard to over 1000 reported cases of decompression sickness every year in the USA alone (3,5).

Decompression sickness (DCS) can manifest itself as a consequence of lowering the barometric pressure after a compressed gas dive and during air travelling situations or during the activity of astronauts on the mission outside the spacecraft in the space. Its effects are often very severe and self-limiting, but it turns out that when recompression treatment with 100% oxygen breathing is used early, there is a good chance of reducing the remaining injury. The most endangered populations include astronauts, flight crew, military and also commercial and recreational divers. Recreational divers are the most numerous group among the people who suffer from DCS and alas, similar condition can be expected in future years (6).

Materials and methods

Material for this literature review was found by two independent authors using PubMed, Cochrane library and ScienceDirect databases. A combination of the keywords, „scuba diving", „risk factors", „decompression sickness", „DCS", was used to identify relevant studies.

The following formulas were used in individual databases:

1) PubMed – "scuba diving" AND "risk factors" AND ("decompression sickness" OR "DCS)";
2) ScienceDirect – "scuba diving", "risk factors", "decompression sickness", "dcs";
3) Cochraine Library – "decompression sickness"

The following exclusion criteria were applied: no Polish or English language version of the article, post-conference summaries, case reports.

The literature review consisted of 3 stages. In the first stage, the publications from 2010 to 2020 were found based on their titles. The second stage consisted of searching and analyzing the titles and abstracts of the works in terms of their purpose and exclusion criteria. In the third stage, full versions of the articles were examined. Finally, 4 publications were qualified for a literature review- fig.1, tab.1.

Figure 1 – flow diagram of data extraction from the literature search.

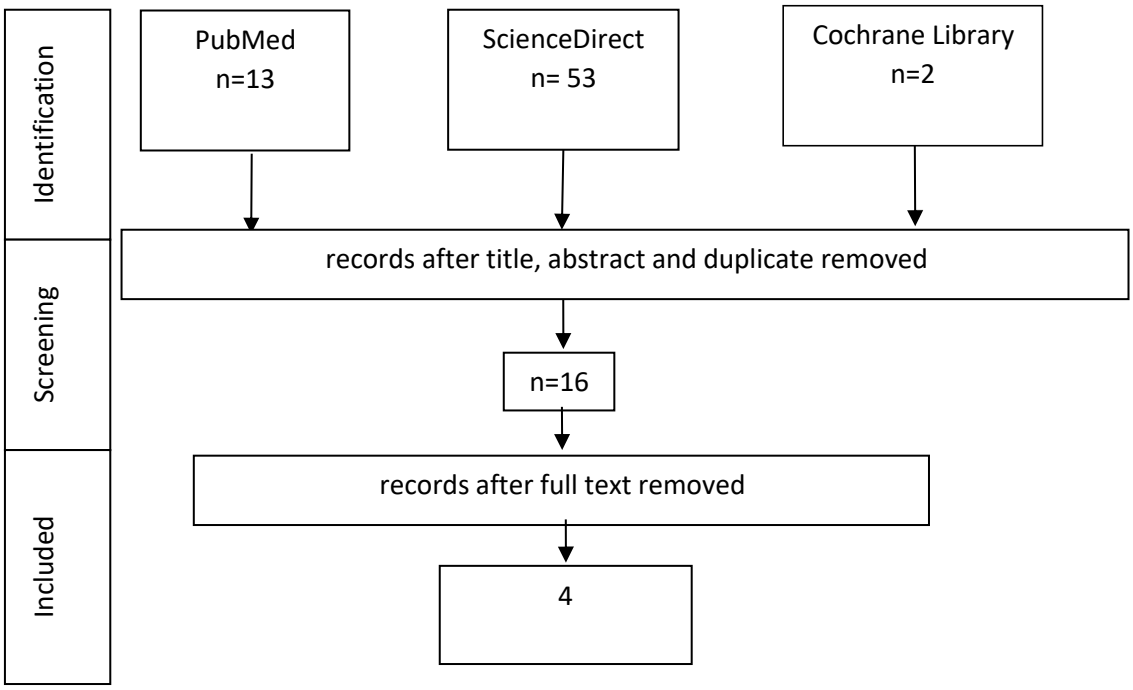

Table 1. Publications qualified for review.

Title, authors, year	Shortened results
High-grade patent foramen ovale is a risk factor of unprovoked decompression sickness in recreational divers, Honek et al. 2019(7)	The research was based on analysis of 169,411 dives. 36 (7%) of the subjects suffered from unprovoked decompression sickness. The divers who already experienced unprovoked DCS had 97.2% PFO (patent foramen ovale) frequency, and the control group – 35.5%. The study was carried out under identical conditions for every diver – the divers did not differ in age, sex, BMI and the number of dives. In the analysis, using adjusted Cox proportional hazards model, high-grade patent foramen ovale proved to be a major-league risk factor for unprovoked decompression sickness.
Dive Risk Factors, Gas Bubble Formation, and Decompression Illness in Recreational SCUBA Diving: Analysis of DAN Europe DSL Data Base Cialoni et al. 2017(8)	In this study, the average depth was 27.1m and gradient factor total 0,66. The diving ascent speed was lower than the newest recommendations and came down to 9-10 meters per minute. According to the authors, there is a statistically proven link between high bubble grades, age, fat mass and amount of dives performed. Also, regarding the prevalence of decompression sickness, the authors identified another significant group of risk factors which are not connected to bubbles and it contains: heavy exercise, sex, strong current, workload during diving.

The relationship of decongestant use and risk of decompression sickness; a case-control study of Hawaiian scuba divers. Smerz R W, 2014(9)	The aim of the study was to explore the connection between decongestant usage and development of DCS. In this study, the authors proved that in the study population risk factors such as dehydration, repetitive diving and violation of dive profiles had significant meaning in developing DCS. Cold, gender, overweight and rapid ascents did not contribute much to developing DCS.
Risks factors for recurrent neurological decompression sickness in recreational divers: a case-control study, Gempp et al. 2014(10)	As part of this study, a group of divers with repeated DCS episode and divers who had a single episode of decompression sickness and carried on diving were analyzed. The authors noted that divers with great experience, the presence of circulatory right-to-left shunt, the lack of changes in the diving style after previous DCS were connected with recurrent episode.

Results

Honek et al. have noted that PFO was a major risk factor in decompression sickness. In Cialoni et al. study BMI and fat mass, age, and diving exposure were acknowledged to have an impact on developing DCS. These authors also stress the role of heavy exercise, sex, strong current, workload during diving in the predisposition to DCS. In the opposite, Smerz R W has claimed that overweight and gender had minor contribution to his study. Gempp et al. are the only authors that present the presence of circulatory right-to-left shunt and the lack of changes in the diving style as the risk factors of DCS.

Discussion

The interest in SCUBA diving is continually increasing, as it is one of the fastest growing sports in the world (10), involving developing number of foreign tourists and employees of the dive industry. Worldwide, the predictable number of qualified divers reaches almost 14 million (12). The growing popularity of diving may have been caused by the many options that diving associations now offer, for example diving under the ice, in caves or wreck diving. As a result of this growth, diving organizations have opened up new locations to be discovered around the world, which further encourages those interested in the underwater world and develops the diving industry (13). International participation in extreme sports has grown visibly, even though athletes are exposed to a significant risk of serious and multiple injuries and even death possibility (14). It can be expected that the number of divers with minor or major health issues and dilemma with differential diagnosis of decompression sickness will increase due to the growing number of active divers. Over the last 30 years, the Croatian Naval Medical Institute has treated over 230 divers due to DCS (15).

Medical personnel dealing with extreme sportsmen and women must be aware of the many differences that must be appreciated between the newly developing area of extreme sports and traditional sports. Considering that extreme sports are associated with high risk and

possibility of death, they differ from traditional sports in that they are usually not competitive and in most cases take place in the natural environment (16,17). These differences can be found in the temperament of the athletes themselves, early post-injury management, treatment decisions and rehabilitation measures (18).

Another aspect that medical professionals dealing with extreme athletes must consider is the processes of adaptation to extreme conditions and activities. Environmental stressors require a complex process of psychophysiological adaptation of the diver aiming to preserve their health, work efficiently and effectively undersea and also overcome the demands of the remarkably extreme environment (19). The underwater environment significantly affects human performance and behaviour, due to the existence of various types of stress factors such as exposure to high pressure, thermal changes, visibility underwater, sensory stimulation, warm conductivity, toxicity of respiratory gases and changes in anxiety (19). The divers need to modify their respiratory and circulatory physiology, along with adapting to changes in the sense organs and progressive lowering of human performance (20). Some of these changes may exceed the body's adaptive capacity and the pathology may develop. According to forensic investigation reports, fatalities from the scuba diving activity are still recorded (21), particularly among amateurs (22). There is a lot of factors that contribute to the divers' deaths and it is necessary to raise awareness of this issue in order to avoid similar events in the future. Diving as any other example of extreme sports does entail certain risk. These risks include decompression sickness, and that is why another important issue for this sport community is an understanding of the mechanism and pathophysiology of DCS. It requires a multi-disciplinary approach which involves diving instructors, co-divers, rescue teams and physicians (23). In conclusion, it is essential to identify risk factors in extreme sports, such as diving, in order to improve prevention of injuries, DCS and deaths, that can happen as a result of the extreme activities.

Taking part in extreme sports activities is associated with the high risk of injury or even death, so athletes - whether professional or amateur, and their medical staff should pay attention to risk factors and methods for injury prevention (18). The reasonable course of thought would be that risk factor analyses are meant for better understanding of the factors contributing to injuries in order to effectively intervene with prevention strategies (24). It is important to emphasise that the health benefits of sport should outweigh the high risk and long-term dysfunction and disability (25).

The prevention of injuries in extreme sports is also important for psychological reasons. Injuries from accidents might have major psychological consequences for the victim, often resulting in depression, anxiety, low self-esteem, tension and anger, especially in seriously injured and ambitious, competitive athletes. The accidents that happened during recreational activities and sports have a particular meaning – that kind of event appear to have an especial and profound psychological impact (26–28). Deterioration of mood and mental health influences the athlete's perception of progress in convalescence and has been proven to have a negative impact on the willingness to continue therapy and participation in rehabilitation sessions (28).

In conclusion, there is a need for research into the ways of accidents prevention and risk factors in some extreme sports, which could hasten the accurate diagnosis and thus the treatment (29). Medical interventions in extreme conditions most often require a combination

of rescue and medical skills and prehospital medicine. Expanded care protocols are an invaluably useful tool in extreme situations, which can be continuously developed by learning and identifying risk factors (30).

Conclusions

Risk factors of decompression sickness (DCS) in scuba diving could be: high-grade PFO, age, diving exposure, strong current, heavy exercise, workload during diving, dehydration, repetitive diving, violation of dive profiles, experience in diving, presence of circulatory right-to-left shunt and the lack of changes in the diving style after previous DCS episode. Further research is needed to verify the role of gender and fat mass in developing symptoms of decompression sickness.

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