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Risk Factors For Decompression Sickness

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Abstract

Over the past few decades, self-contained underwater breathing apparatus (SCUBA) diving has gained popularity globally. Efforts to explore new trails underwater have rapidly expanded recreational, technical, professional, and military diving opportunities. Decompression sickness (DCS) is an essential and complex health problem among divers, stemming from changes in environmental pressure during and after underwater travel. Understanding the various risk factors associated with DCS is critical in implementing safe diving practices. Medical professionals, regardless of specialization, need to be aware of the adverse effects of changes in exposure to environmental stresses on the human body. Decompression sickness (DCS) can occur quickly, immediately, or very mildly and is delayed. Divers with DCS can arrive late, far from the dive site, due to their varied presentation, slow start, and air travel after diving. Medical personnel must consider the previous days' activities and be aware of diving problems and disorders to take advantage of the opportunity to diagnose and treat such patients appropriately. Individual and environmental risk factors play a role in increasing the incidence of DCS in divers, including obesity, smoking, alcohol, anxiety disorders, comorbidities, previous injuries, cold water, duration, and depth of diving. A comprehensive understanding of these multifaceted risk elements is essential for divers and medical professionals. Armed with this knowledge, they can better assess potential risks, adopt proactive precautions, and ensure diver safety, ultimately reducing severe DCS incidents.

Keywords: *Efforts to explore new underwater pathways have rapidly expanded recreational, Technical, Professional, and Military diving opportunities.*

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Introduction

The increase in environmental pressure, the difference in breathing gases used for diving (with different fractions of inert and saturated gases), the rules governing their behavior, and the correct decompression procedure are considered widely known. Generally, decompression tables or dive computers are used to control DCS risk by using the concept of "master network" to calculate the depth and stopping time of decompression (Cialoni et al., & Marroni, 2017). Nonetheless, several other individual and environment-related risk factors have been identified to increase the risk of DCS events. Individual factors include a high body mass index (BMI), smoking, a previous history of DCS, and a patented foramen ovale. At the same time, environmental factors are related to cold sea water temperatures and heated diver suits. Some of these risk factors have been elucidated mechanisms associated with increased risk of DCS. In contrast, others are still being studied (Cooper & Hanson, 2019) (Savioli et al., 2022). This literature review discusses decompression sickness, especially in divers, and describes related risk factors according to the novelty of the literature.

Research Methods

A comprehensive search of electronic databases was conducted to identify relevant studies published between January 2009 and December 2023. The inclusion criteria are (1) observational or experimental studies examining risk factors in decompression sickness and (2) the study was published in a peer-reviewed journal. Two reviewers independently screened the study titles and abstracts identified in the search, and the full-text article was reviewed for notability. Quality assessments of the included studies were conducted using the Newcastle-Ottawa Scale. Data is extracted and synthesized using narrative synthesis.

Results and Discussion

Definition and Classification of *Decompression Sickness*

Decompression sickness (*Decompression Sickness/DCS*) occurs when a dissolved gas (usually nitrogen or helium, used in diving or diving with a mixture of gases) escapes from solution and forms bubbles in the body as pressure drops occur (Pollock & Buteau, 2017).

Decompression sickness (*Decompression Sickness/DCS*) can occur during underwater dives (at the time of elevation), working in caissons, flying in unpressurized aircraft, and activities outside the spacecraft. However, this literature review is devoted to DCS due to diving, where appropriate decompression procedures can help reduce the risk of DCS, which is different from other conditions where it may be challenging to perform (Edge & Wilmshurst, 2021).

Experts categorize DCS into Type I, with symptoms involving the skin, musculoskeletal system, or lymphatic system only, and Type II, with symptoms involving the central nervous system. Decompression sickness (*Decompression Sickness/DCS*Type I is characterized by one or a combination of the following symptoms: (1) mild pain that begins to disappear within 10 minutes after the onset of pain (niggles); (2) pruritus, or "twisted skin/*Skin Bends*"(Figure 2.1.), which causes itching or burning of the skin; and (3) *Cutis marmorata* (Figure 2.2.) (Mitchell et al., 2018).

Figure 2.1. *Skin Bends* on Divers
(Source: *Divers Alert Network*)

DCS type II has the following characteristics: (1) pulmonary symptoms, (2) hypovolemic shock, or (3) nervous system involvement. Pain only occurs in about 30% of cases. Due to the central and peripheral nervous system's anatomical complexity, signs and symptoms vary. Symptoms usually occur immediately but can occur up to 36 hours later.

Figure 2.2. *Cutis Marmorata* on DCS
(Source: Kalentzos, 2010: [9])

Etiology

Decompression sickness (*Decompression Sickness*(DCS) is the formation, growth, and elimination of bubbles caused by decreased environmental pressure that produces an inert gas, usually nitrogen, that dissolves in solution within body tissues. Rapid changes in breathing air pressure and increased amounts of oxygen and nitrogen in various body tissues eventually lead to this condition. As stated by Henry's law (*Henry's law*), at a constant temperature, the amount of gas dissolved is proportional to its partial pressure above the liquid. Individuals who breathe air in a pressurized environment reach a gas equilibrium/saturation state. This dissolved gas will be removed from the solution when it leaves a high-pressure environment to a lower-pressure environment, such as rising from depth during *Self-contained underwater breathing apparatus* (SCUBA), leaving the job site *caisson*, or climbing to altitude indoors without pressurization.

Epidemiology

In the United States, between 1987 and 2003, the Sports & Fitness Industry Association (formerly the Sports Equipment Manufacturers Association) estimated that the number of scuba divers who dived at least once a year increased by 32.1% from 2.4 to 3.2 million participants. However, during the 6 years 2000-2006, there was a decrease of 23% to 3.2 million. The peak year was in 1998 at 3.5 million. However, it is estimated that only about one-third of divers were active or regular participants. About two-thirds of divers are regular or novice divers. In 2015, more than 23 million scuba diver certifications have been issued worldwide, with an estimated 7 million active divers. Experience results in safer divers, although, on the other hand, excessive self-confidence can lead to motivation that exceeds the limits of ability (Glazer & Telian, 2016).

As a result of variability in reporting and information gathering, medical journal publications on diving-related injury statistics need to be more consistent. In this case, to improve the collection of statistical information, *the Divers Alert Network* (DAN), based in North Carolina in the United States, acts as a medical information and referral service for diving-related injuries. In addition to these roles, the institution provides education, acts as an information institution (*clearinghouse*) for diving-related injury reports from around the world, and participates in research related to diving injuries and illnesses. They also sponsor a long-term *Project Dive*

Exploration (PDE) research study. According to DAN, less than 1% of divers experience DCS (Lautridou et al., 2020).

If proper decompression procedures are followed, DCS is also rare. Incidence rates (per dive) in open water operational dives of a duration of a few minutes to several hours vary by dive population: 0.015% for scientific divers, 0.01–0.019% for recreational divers, 0.030% for U.S. Navy divers, and 0.095% for commercial divers (Savioli et al., 2022). This figure is much higher when diving in cold water than in warm water. These figures are all based on many dives done well within the maximum exposure limits of the accepted procedure (decompression table or computer); therefore, these data underestimate the actual level at the maximum limit. In addition, for long-term exposure in hot conditions and stressful sports, the U.S. Navy's trial dive aims to develop a new decompression procedure having a rate of 4.4 DCS cases per 100 dives (Savioli et al., 2022) (Atwell et al., &; Cooper, 2019).

Pathophysiology of DCS

The physical law that most underlies adaptive change and the development of decompression pathology and how to overcome it is Henry's law (*Henry's Law*). This law, formulated by William Henry in 1803, states that "a gas exerting pressure on the surface of a liquid shall enter into the solution until it reaches the same pressure in the liquid as the pressure exerted on that surface." According to this law, at a constant temperature, the solubility of a gas is directly proportional to the pressure that the gas exerts on the solution (Savioli et al., 2022).

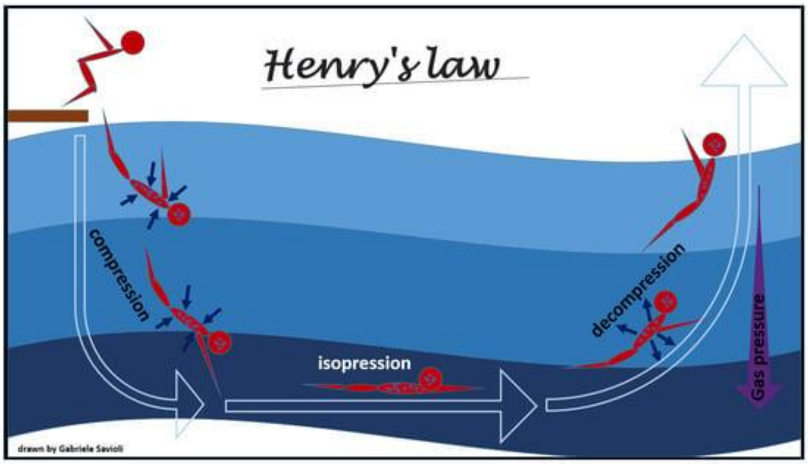

Figure 2.2. Henry's Law
(Source: Savioli and colleagues)

Once equilibrium is reached, the liquid is defined as saturated with that gas. When the pressure increases, another gas will enter the solution, while when the pressure decreases, the liquid will be in a saturated situation. The gas will be released to the outside until the pressure is balanced again. According to this principle, when the environmental pressure decreases during decompression, the tissue becomes saturated with an inert gas, and therefore, the gas tends to leave the solution and form a free gas. Due to the metabolic activity of oxygen and carbon dioxide, oxygen saturation and carbon dioxide rarely contribute to the formation of phases (Savioli et al., 2022) (Edge & Wilmshurst, 2021).

Since transferring gases into the grid is a dynamic process, it takes time to balance the grid and the environmental partial pressure of the inert gas. Some time is required to achieve equilibrium of tissue gas concentration at a specific pressure. Inert gases escaping the tissue follow a similar kinetic pattern when the ambient pressure decreases. Studies have shown gradual decompression with a set pause can minimize saturation levels. Mathematical models regarding different types of tissues and gases have been developed to explain this step, and valuable tables have been created to determine the decompression time. It should be noted that, due to this principle, reaching a certain altitude level (for example, flying in a commercial aircraft) within 12-18 hours after diving can result in the formation of free gases in the tissues, even following established protocols for safety. Decompress (Hadanny et al., 2015).

When returning to atmospheric pressure from increasing the surrounding pressure, organisms now in a nitrogen-saturated state need sufficient time to remove this inert gas. Inert gases carried with inhaled air have indeed been dissolved in tissues, especially in lipid-containing tissues (adipose tissue and myelin sheath), in amounts directly proportional to environmental stress and exposure time (Edge & Wilmshurst, 2021) (Cialoni et al., 2017).

The decompression table is elaborated based on biological, mathematical models calculating the time required to remove saturated nitrogen quotas without biological damage. Failure to respect and determine the pathogenetic moment of the decompression syndrome. Nitrogen is released in the gas phase, forming bubbles in the cellular, interstitial fluid, and circulation environment, which can cause embolism. At the interface with interstitial fluid and plasma, bubbles can also indirectly activate intrinsic coagulation pathways, platelet aggregation, and factors responsible for the inflammatory cascade (Savioli et al., 2022).

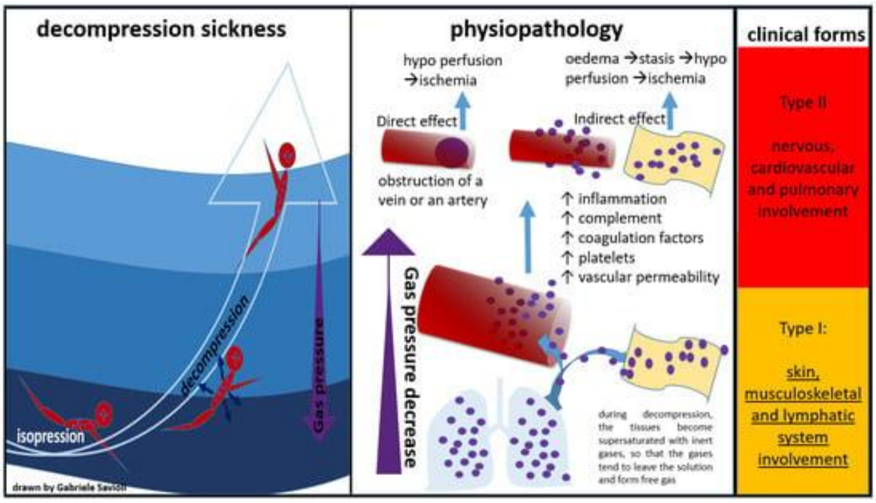

Figure 2.3. Pathophysiology of DCS
(Source: Savioli and colleagues)

Clinical manifestations

Decompression sickness (*Decompression Sickness*/DCS) is an acute attack. However, the onset time of symptoms varies from individual to individual, and although signs and symptoms generally occur within two hours after activity in an environment with higher pressure than atmospheric (hyperbaric) environments, it can last from a few minutes to 24 to 48 hours. Most cases of DCS occur as soon as they surface, with 98% occurring within 24 hours. However, the clinical picture may appear after 48 hours in some rare cases. This situation resembles scuba dives performed with a self-contained breathing apparatus (ARA or SCUBA-AIR). Decompression sickness (*Decompression Sickness*/DCS) can also occur after exposure to high pressure or rapid pressure loss in the aircraft cabin.

Bert was the first to describe the pathophysiology of DCS in his milestone"*La Pression Barometrique*," published in 1878. Furthermore, in the early 20th century, autopsy studies on divers and caisson patients showed that DCS was caused by free gas in blood and tissues. Hallenbeck later became the first to show that platelet activation, coagulation, and impaired capillary permeability (with plasma leakage into the extravascular) correlate with bubble surface activity.

DCS Type 1: Involvement of the Skin, Musculoskeletal, and Lymphatic System

Type DCS 1 is the most common type of DCS and causes joint pain that is often mistaken for pain from injury. It is the mildest DCS, with no neurological, cardiovascular, or respiratory symptoms present. Patients may complain of general lethargy, asthenia, and fatigue. The most common manifestation is joint pain, which stems from the fact that movement of the bones of the head can cause negative pressure, thereby attracting gas bubbles. The shoulders and elbows are the most commonly involved joints. Myalgia of varying localization is also common, and this condition is an expression of activation of nitrogen-mediated inflammatory circuits. Symptoms of musculoskeletal involvement may disappear within a few hours or persist for 4-5 days. A previous history of musculoskeletal DCS increases the risk of osteonecrosis (Howle et al., 2017).

Osteonecrosis can occur in divers who experience deep exposure *caisson*, diving instructors, and commercial divers. Additional and less frequent presentations involve the cutaneous and lymphatic systems, which can cause itching, marble formation, and puffy skin with an orange-peel-like appearance. One form of particular skin involvement is *cutis marmorata*, which usually appears as itchy or painful red or blue patches. It is generally considered a mild form of DCS and requires high-pressure recompression therapy. This condition can be treated with oxygen inhalation. A patent foramen ovale has been observed associated with the presence of *patent foramen ovale* (PFO) in the heart, with a prevalence of almost 100%. *Cutis marmorata* rarely has other symptoms of DCS. These symptoms are usually blurred vision, dizziness, and mild vagus or systemic brain disorders (abnormal fatigue, stiffness, poor concentration, etc.). The etiology of these other symptoms is embolic, and cutis marmorata can also be a symptom of gas bubbles that embolic into the brainstem. Site of regulation of skin blood vessels for dilation and contraction of the skin by the autonomic nervous system (Sharareh & Schwarzkopf, 2015).

DCS Type 2: Nervous, Cardiovascular, and Pulmonary System Involvement

This type is a severe, though less common, form of DCS and can cause permanent damage and, in rare cases, death. The spinal cord is the most common site affected by DCS type II. Symptoms resemble spinal cord trauma and usually involve the lumbar spine or lower back. Its onset is often characterized by paresthesia and strength deficits up to paraplegia, neurological bladder, intestinal or bladder incontinence, and sexual impotence. When DCS affects the brain, many symptoms can appear, and the clinical picture may be dominated by ataxia, nystagmus, visual impairment, language disorders, behavioral changes, seizures, and even coma. These manifestations usually result from deep and prolonged dives and often result in permanent deafness (Jain et al., 2017).

Heart or respiratory symptoms begin with retrosternal depression or pain associated with cough or dyspnea. In some cases, bronchospasm may occur. The changes that occur in the case of pulmonary circulation embolization are characteristic of acute pulmonary heart failure and right heart failure. In some cases, right heart failure can lead to coma or death. Embolization of coronary arteries or large heart cavities can also cause a heart attack (Savioli et al., 2022).

Pulmonary vascular obstruction usually occurs when large amounts of gas transit in the venous system. Clinically, this causes chest pain, dyspnea, and coughing. This presentation occurs in about 2% of all DCS cases and can eventually lead to death. Symptoms can appear up to 12 hours after diving and last 12–48 hours. Pulmonary barotrauma may be associated with DCS type 2 with pulmonary involvement in cases of rapid ascent (Savioli et al., 2022).

Management

Since the presence and detection of gas embolism is usually the first evidence of the presence of free gas, examination of the pulmonary artery with *a Computed Tomography* (CT)

Scan of The thorax can be used to detect it. Further, examination *Ultrasonography* (Ultrasound) can also be useful (Savioli et al., 2022).

In the form of DCS with immediate attack, the first intervention can be carried out at the scene of the decompression accident and mainly includes the support of vital functions following the general guidelines for cardiopulmonary resuscitation. Oxygen needs to be administered as soon as possible with an oronasal mask on $FiO_2 = 1$, and the absence of nitrogen in the mixture favors its elimination by the body (Savioli et al., 2022).

The administration of intravenous or oral fluids to conscious patients to expand the volume and improve blood rheology should be considered from the outset. During hospitalization, the already described action can be integrated with administering nonsteroidal anti-inflammatory drugs, which are helpful in arthralgic manifestations. Some research suggests that additional interventions, such as nonsteroidal anti-inflammatory drugs (NSAIDs) or recompression with helium in addition to oxygen, may reduce the recompression time required. For example, the use of NSAIDs reduces the average number of recompression sessions required from three to two. The use of either of these strategies may be justified. More research is needed. Antiplatelet agents, such as aspirin, may be given to counteract platelet activation caused by free gases in the blood and for their ability to counteract increased platelet and erythrocyte aggregation (Jain et al., 2017).

In case of neurological bladder development, a bladder catheter needs to be installed. Transportation of patients to centers equipped with hyperbaric implants must be prepared quickly. Aerial vehicles require pressurized cabins or low-altitude flights to avoid further decompression of the patient.

Therapeutic recompression, which means the delivery of 100% oxygen for several hours in an enclosed room pressurized >1 atmosphere, slowly lowering the pressure to atmospheric pressure, may be necessary and has three primary purposes (Brackett, 2019)

1) Reduces the volume of bubbles present in the body, following Boyle's Law, and thus reduces embolic resistance to blood flow. This will reduce the total surface of the bubble with the consequent reduction of interaction with intercellular fluid and plasma and, in turn, reduce the activation of clotting, platelet aggregation, and inflammatory processes;
2) Increases the absorption of bubbles in body fluids and the removal of inert gases from the lungs through the dissolution of nitrogen present in the bubbles (Henry's Law);
3) Improves oxygen supply to peripheral tissue cells.

DCS Risk Factors

Several risk factors have been identified to increase the incidence of DCS. However, some of the mechanisms are still being researched today. DCS risk factors, especially when diving, can be divided into risk factors derived from the individual himself and environmental factors that may play a role.

Individual Risk Factors

1) Smoke

Smokers are exposed to toxic chemicals in cigarettes, especially carbon monoxide (CO), which binds tightly with hemoglobin in the blood, reducing the blood's ability to transport oxygen. This condition can impair blood and oxygen flow to tissues, including those affected by DCS. In addition, smoking has been shown to damage the lungs and cause a decrease in lung capacity, thereby reducing the body's ability to remove dissolved gases, including nitrogen, during decompression. This can increase the risk of gas bubbles forming in the body further during decompression. Nevertheless, the results suggest that the pros and cons of smoking as a significant risk factor in the increased incidence of DCS.

The study conducted by Buch and colleagues used DCI reports recorded in a database *called Divers Alert Network* (AND) from 1989 to 1997 and evaluated the association of smoking status with DCS/DCI severity. A total of 4,350 patients were included in the analysis, the results showed that heavy smokers were more likely to experience severe vs. mild symptoms than nonsmokers (OR = 1.88) (95% CI 1.36, 2.60) or light smokers (OR = 1.56) (95% CI 1.09, 2.23). Heavy smokers and light smokers were more likely than nonsmokers to experience severe vs. moderate symptoms (OR = 1.36) (95% CI 1.06, 1.74) and (1.22) (1.02, 1.46). Study results are consistent with the trend that when DCS occurs, smoking triggers more severe symptoms.23 In contrast to the results of studies conducted by Duke and colleagues, smoking, alcohol consumption, and obesity were not shown to be risk factors influencing the incidence of DCS in divers (Duke et al., 2016).

2) Drink alcohol the night before diving.

Alcohol can cause dilation of blood vessels (vasodilation), which can increase blood flow to tissues. This condition can cause an increase in the pressure of blood-soluble gases, such as nitrogen, during a dive. This gas can escape from the solution when decompression occurs and form bubbles. Alcohol can also impair coordination and judgment, which can lead to riskier diving behaviors and poor decisions, such as increased dive depth without adhering to the correct decompression table.

In a study Kongkamol and colleagues conducted, conducted on fishermen divers in Thailand, examined that Body mass index (BMI), alcohol consumption, diving depth, and duration of time at sea/diving were significantly associated with DCS ($p < 0.05$) (Kongkamol et al., &; Sathirapanya, 2023).

3) Gender

The debate over gender risk factors has been ongoing for the past few years. Initially, the increased risk of male-sex-related DCS was due to the prevalence of divers who were more dominant were men. However, the increased interest of recreational divers in women changes the risk rate for DCS events. Studies conducted by Webb, Kannan, and Pilmanus showed no significant differences in the sexes regarding incidence rates. However, precordial venous gas embolism (VGE) occurs much higher in men than women under the same exposure conditions of 69.3% and 55.0%. Women who used hormonal contraceptives showed a much greater susceptibility to DCS than those who did not use hormonal contraceptives during the last two weeks of their menstrual cycle (Jain et al., 2017).

4) Previous DCS History

Individuals who have experienced DCS before have a higher risk of experiencing DCS again in subsequent dives. This factor can be related to the susceptibility of individuals to pressure changes and the development of gas bubbles in their bodies. Obesity can exacerbate this risk if more nitrogen is stored in body tissues.

5) Obesity

Obese individuals have a higher accumulation of body fat, including in specific tissues such as cartilage and adipose tissue (fat). Body fat is more capable of absorbing gases, including nitrogen, that can cause DCS. As a result, fatter individuals may have more significant nitrogen reserves in their bodies after a dive, which can increase the risk of DCS.

Obesity can affect the body's metabolism, including dissolving and eliminating gases in the blood and tissues. This disruption in metabolism can affect how the body handles dissolved gases during and after the dive, increasing the likelihood of DCS. Obesity is often linked to health problems such as high blood pressure and heart disease. Pre-existing cardiovascular conditions can affect the body's response to pressure changes during and after a dive. Further, this condition can affect blood circulation and gas distribution, potentially increasing the risk of DCS. Obesity can also affect an individual's breathing patterns. Inefficient or shallow breathing during a dive can result in nitrogen deposition in body tissues. If not removed correctly during the decompression process, nitrogen can form gas bubbles that potentially carry a DCS risk.

6) Anxiety/panic disorder

Anxiety and panic disorders have the potential to interact with DCS in a variety of ways, mainly because of the psychological and physiological responses they trigger. Anxiety and panic disorders often involve an increased stress response. Stress can affect overall body functions, including the cardiovascular system. When individuals with anxiety disorders experience stress before or during diving, this can lead to changes in breathing patterns and increased heart rate, potentially affecting their susceptibility to DCS.

Anxiety and panic attacks are often associated with rapid, shallow breathing or hyperventilation. Maintaining the correct breathing pattern is essential during diving, especially in deep or prolonged dives. Hyperventilation can lower carbon dioxide levels in the body, potentially increasing the risk of DCS by altering gas exchange dynamics. People with anxiety disorders may be more alert or risk-averse in their diving practices. This can have both positive and negative impacts. Additionally, they may be more diligent in following safety protocols and adhering to strict dive table or dive computer recommendations. Excessive opposing sides can lead to lost opportunities for a pleasant and safe diving experience.

Individuals with anxiety or panic disorders are often well aware of their physical sensations. This increased awareness can sometimes lead to a tendency to misinterpret normal bodily sensations as a sign of DCS or other health problems. This has the potential to cause unnecessary worry or overreaction. Panic attacks while diving can be hazardous, as they can interfere with a diver's ability to make rational decisions and follow emergency procedures. Panic can lead to rapid ascent or other unsafe behaviors that increase the risk of DCS.

People with anxiety or panic disorders who wish to dive should consult a mental health professional and dive medicine professional. They may benefit from strategies for managing anxiety before and during diving, such as relaxation techniques or cognitive behavioral therapy. Medications used to treat anxiety may also be considered. However, their effects on dive safety should be thoroughly discussed with a healthcare provider.

7) Poor Cardiorespiratory Fitness

Poor cardiorespiratory fitness refers to a physical condition in which a person has low cardiorespiratory capacity. This includes the capacity of the lungs to transport oxygen, the capacity of the heart to pump blood, and the body's ability to use oxygen efficiently. When a person is not in good fitness, his body may not be able to cope well with the pressure changes that occur during diving. This is because changes in underwater pressure can affect blood circulation, tissue oxygenation, and nitrogen release from tissues. In poor fitness conditions, the body may be more susceptible to nitrogen accumulation in tissues, increasing the risk of DCS.

8) Old age

As a person ages, several physiological changes occur in his body. One is a decrease in the elasticity of tissues, including lungs and blood vessels. This can affect,t the body's ability to adjust to pressure changes that occur during diving. In addition, old age is often a risk factor for specific medical conditions, such as atherosclerosis, which can impede blood flow and affect gas exchange in the body. All of these can contribute to an increased risk of DCS in older divers.

9) Disorders or comorbidities that affect the efficiency of the lungs and blood vessels

Disorders or diseases that affect the efficiency of the lungs and blood vessels can be a significant risk factor. For example, Chronic Obstructive Pulmonary Disease (COPD) or asthma can interfere with airflow and gas exchange in the lungs. The presence of foramen ovale is a risk factor for developing DCS in divers because it allows entry of venous embolism into the systemic circulation. The fetus may be at risk for DCS in pregnant divers. Pulmonary filters do not work in the fetus. Bubbles produced by fetal tissue or placenta will pass through the foramen ovale into the fetal arterial circulation, where they can cause embolism of the brain, spinal cord, and other organs.

10) Previous Musculoskeletal injuries

Previous musculoskeletal injuries, especially those involving joints or bones, can increase the risk of DCS. The injury may cause the presence of areas that are prone to the development of gas bubbles. When the pressure changes during the dive, this area can become a potential source for gas bubbles to form. In addition, musculoskeletal injuries can also affect blood circulation around the injury area, which can worsen the risk of DCS. The study, conducted by Gottschalk and colleagues, states that experimental rats that experience musculoskeletal injury have a significantly increased risk of developing DCS compared to controls. Human studies have yet to come up with conclusive conclusions, which could be due to a lack of historical examination of previous injuries.

11) High-fat diet

Kaczerska and colleagues, in their study on the effect of postprandial hypertriglyceridemia on the risk of decompression stress after exposure to hyperbaric air, reported that after each hyperbaric exposure, decompression stress was found in 30 of the 55 subjects. Postprandial hypertriglyceridemia and hypercholesterolemia increase the risk of stress decompression after exposure to hyperbaric air.

A diet high in fat, mainly if it contains saturated fat and high cholesterol, can affect the nature of the blood. High levels of fats in the blood can affect blood viscosity, which means the blood becomes thicker. Thicker blood can impede blood flow to tissues and organs, affecting the body's ability to cope with pressure changes during a dive. In addition, thicker blood can also increase the risk of blood clot formation, clogging tiny blood vessels and triggering circulation problems. All of these can affect the body's response to DCS.

Environmental Factors

1) Cold Exposure After Diving/Diver Cold during Recompression

After diving, the body generally becomes cooler because water has a high heat conductivity. When a person does not wear appropriate clothing or does not maintain their body temperature, the risk of hypothermia increases. Hypothermia can affect blood flow and metabolism and the body's ability to remove dissolved gases, such as nitrogen, during decompression.

2) Cold water (vasoconstriction lowers nitrogen removal)

Cold water can have a significant impact on a diver's body. When exposed to low water temperatures, blood vessels in the skin will narrow (vasoconstriction) in response to maintaining body heat. This vasoconstriction aims to reduce blood flow to the skin and prioritize blood flow to essential core organs, such as the heart and brain. During the dive, nitrogen from the air inhaled by the diver will dissolve in the body tissues. As divers rise to the surface, environmental pressure decreases, allowing this dissolved nitrogen to escape the tissue as bubbles. If the body experiences significant vasoconstriction due to cold water, blood flow to peripheral tissues (such as the skin) may be reduced more. This means that peripheral areas may experience a more significant decrease in blood flow, making the release of nitrogen from tissues slower. As a result, more nitrogen bubbles may form and risk causing DCS.

3) Poor sea conditions, heavy currents

Poor ocean conditions with heavy currents can provide additional challenges for divers. Strong ocean currents can force divers to make extra efforts to stay in the desired position, allowing the body to expend energy and produce more nitrogen in the tissues. In addition, poor ocean conditions often mean divers will spend more time underwater, which can increase pressure on body tissues and affect decompression.

4) Heated wetsuit (causes dehydration and increases nitrogen upload)

A heated wetsuit is a device to maintain a diver's body temperature underwater, especially in cold water. However, using heated wetsuits also has side effects to be aware of. One effect is the potential for dehydration. While in a wetsuit, divers may feel more comfortable and less aware that they are still losing body fluids through sweat and breathing. Dehydration can cause blood to become thicker, affecting blood circulation and releasing nitrogen from tissues as it rises to the surface. In addition, when a person feels comfortable in a heated wetsuit, they tend to spend more time underwater, which allows for more excellent nitrogen absorption in tissues.

5) Depth and Duration of Dive

The depth and duration of the dive play an essential role in DCS risk assessment, as more profound and longer dives increase the likelihood of this condition occurring. The speed at which divers rise from the depths is equally important, with rapid surfaces increasing susceptibility to DCS due to pressure fluctuations.

Conclusion

1. Decompression *sickness* (DCS) occurs when dissolved gases (usually nitrogen or helium, used in mixed gas diving) escape from the solution and form bubbles in the body when the pressure drops. DCS can occur during underwater dives (at the time of elevation), while working in kaisons, flying in unpressurized aircraft, and doing activities outside the spacecraft.
2. Experts categorize DCS into Type I, with symptoms involving the skin, musculoskeletal system, or lymphatic system only, and Type II, with symptoms involving the central nervous system.
3. Risk factors for DCS events can be classified into individual and environmental factors. Individual factors include obesity, smoking, alcohol consumption before diving, poor cardiorespiratory fitness, patency of the foramen ovale, high-fat diet and dyslipidemia, old age, disorders or diseases affecting lung and blood vessel efficiency, previous musculoskeletal injuries, and anxiety/panic disorders. Environmental factors include cold water temperature, exposure to cold/cold during recompression, heavy ocean currents, heated wetsuits, and depth and duration of diving.

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