Breath-hold Diving and Its Potential Health Risks

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Abstract

Breath-hold diving is the oldest form of diving, practiced commercially, competitively and recreationally. Recently, there has been a surge in its popularity in a wide range of the population, but the potential health risks are somewhat overlooked.

This article provides an overview of the physiological changes that occur during breath-hold diving, and how these changes can affect a diver's well-being. Multiple organs are affected by the changes in pressures causing injury to a diver such as barotraumas, and in rare cases, "*Taravara Syndrome*". Breath-hold divers are also exposed to the elements of nature which can be dangerous to the diver, capable of injuries and fatalities. These include strong and unpredictable currents, dangerous rocky terrains, and marine animals.

The objective of this article is to raise awareness among breath-hold divers, especially those who are new and inexperienced. As breath-hold diving is becoming more and more popular, knowledge of hazards and physiological change can be beneficial and key to the prevention of potential injuries and fatalities.

Keywords: breath-hold diving, diving physiology, diving hazards

Introduction

Breath-hold diving is the oldest form of diving dating back to ancient Greek times. It is currently practiced commercially, competitively, and recreationally. The most well-known commercial breath-hold diving was documented 2,000 years ago in Japan and Korea, known as Ama pearl divers and Hae-Nyu divers[1]. Recently, there has been a surge in popularity of breath-hold diving for recreational purposes, known as freediving, due to its relatively lower cost, no requirement for certifications, and convenience for a weekend trip. As for the field of competitive breath-hold diving, the sport is receiving increasing interest, as it poses a challenge for the extreme population, looking to be one with the ocean, and mastering the ultimate self-body and mind control. With the growing

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popularity of breath-hold diving, it is best that divers are aware of the physiological changes that occur, the potential hazards one might encounter, and safe pressure equalization techniques. This article provides an overview on the physiological responses to breath-hold diving, potential health hazards, and injuries associated with it. The objective of this article review is to provide guidance and knowledge to people interested in breath-hold diving.

Physiological Responses to Breath-hold Diving

Breath-hold divers are exposed to multiple factors that contribute to physiological changes in the human body. During a dive, the diver is exposed to the elements of the ocean, changing temperatures, and increasing in ambient pressures due to greater depths. Until recently, it was believed that lung volume was the limiting factor for how deep a diver could go. The proposed theory was simple, according to Boyle's Law, a diver with a total lung capacity (TLC) of 6 liters and a residual volume (RV) of 1.5 liters would be able to perform a breath hold dive no deeper more than 30 meters[2], as beyond this depth the lungs would compress to a volume smaller than the RV, which can result to lung squeeze[3] Therefore, the ratio of TLC:RV was considered the determining factor. This theory was later disproven as divers reached depths of over 100 meters and currently the world record for no limits dive stands at 214 meters by Herbert Nitsch[4]. An important physiological change is the redistribution of blood from periphery to intrapulmonary vessels, allowing the RV to decrease further as blood replaces the air in the alveoli. It is estimated that around 1 to 1.5 liters of blood is redistributed into the lungs at depth (see Fig. 1)[5].

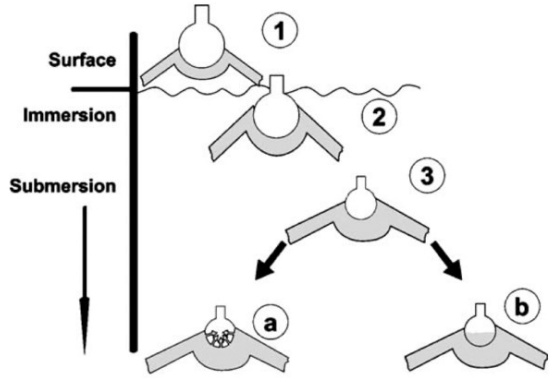


Figure 1. The changes occurring in the alveoli during breath-hold diving
(1) At surface, alveoli and pulmonary vessels are normal in diameters (2) Immersion creates negative intrathoracic pressure, causing blood to shift into the pulmonal vessels (3) Submersion while breath-holding compresses the alveoli, causing more blood to be redistributed leading to engorgement of the vessels. At greater depths, it can lead to ruptured vessels (a) or intra-alveolar edema (b)[3]

Another important physiological response in breath-hold divers' is the "*Mammalian Dive Reflex*" (MDR). This reflex is triggered by facial immersion in cold water. It is characterized by bradycardia, peripheral vasoconstriction, and blood shifting to the lungs, which collectively serve to conserve oxygen and extend the duration of breath-hold. MDR is most pronounced in aquatic mammals but is also present in humans. This reflex plays a critical role by slowing the heart rate to reduce oxygen consumption, redirecting blood flow to vital organs, and preventing lung collapse under pressure through the blood shift mechanism. These adaptations become increasingly pronounced with increased depth and duration of the dives, allowing trained divers to reach impressive depths and hold their breath for several minutes. Elite breath-hold divers also exhibit tolerance to high carbon dioxide and low oxygen levels, suggesting that MDR can be trained and amplified through repeated exposure and conditioning. Understanding MDR is fundamental to grasping the physiological limits and capabilities of human breath-hold diving performance[6-8].

Potential Health Risks and Injuries

With increasing depth, another area of concern is barotraumas that can occur in any air spaces found on a diver, this can be both anatomical or from the equipment of the diver (see Fig. 2).

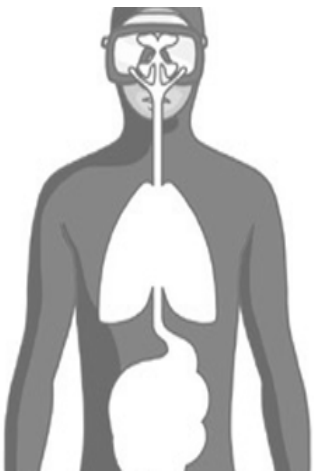


Figure 2. These are the air spaces subjected to compression and expansion once exposed to changes in pressure (sinuses, upper airway, lungs, stomach, and bowel). (*Modified from* British sub-aqua club "Ocean diver module")[9]

The common term for barotrauma is the air space followed by the word "squeeze", for instance, barotrauma of the mask is referred to as a "mask squeeze". The most common Squeeze is of the middle ear and sinuses. This can be very painful but is

not life threating and can be prevented if proper pressure equalization techniques and precautions are considered pre-dive, such as avoidance of diving during a cold. There are various techniques for ear pressure equalization. The easiest to understand is the Valsalva method, but the most effective in breath-hold diving is Frenzel's technique, as the diver can perform this technique activating the muscles of the soft palate, rather than increasing the pressure with the limited air. However, this technique requires a lot of training to be properly executed.[10-12] On the other hand, equipment squeeze can be easily prevented with properly fitted apparel and breath-hold diving-specific equipment. A more severe and life-threating barotrauma of the lungs, caused by the rupture of capillaries and extravasation of blood into the alveoli, due to increasing negative pressures at depth. This phenomenon is called "pulmonary barotrauma of descent".

Another obstacle of breath-hold diving is the duration of the dive and the changes in partial pressures of gases. In breath-hold diving, the diver takes one gulp of air at surface, goes down to depth, and returns to the surface. The partial pressures of oxygen and carbon dioxide change during the dive. With this in mind, divers are exposed to the risk of hypoxia, leading to blackouts as the duration of the dives increases. This is due to the body using up oxygen for exertion and production of carbon dioxide due to cellular respiration, and the changes of pressure during ascent further decrease the partial pressure of oxygen as the volume expands, leading to hypoxic blackout, which leads to drowning[13-16].

There are multiple dangers when breath-hold diving, and like any other outdoor activities, the elements play an important part. The potential environmental hazards a diver may encounter are as follows: underwater currents, dangerous marine animals, increased pressures, and potential diving injuries[15-17].

One of the most frequent and unpredictable environmental hazard is underwater currents. These can affect a driver by causing overexertion, which increases consumption of oxygen, resulting in a state of hypoxia earlier than expected. This condition can lead to fatal injuries, and therefore, drivers are advised to never ignore the urge to breath, and to be aware of their ability and not overestimate it. Inaddition, marine animals can also cause injuries to a diver, resulting in physical injuries and envenomation. Marine predators such as sharks, barracudas, trigger fish, moray eels, sea lions and giant squid/octopus[17], have been known to attack humans. Even though these incidents are low compared to other injuries, they can sometimes be fatal. Envenomation from marine animals is much more common. Jellyfish are responsible for most of the envenomation with varying symptoms from minor rashes to life-threatening condition known as "*Irukandji Syndrome".* It is advised that divers wear proper protective gear and avoid diving in known jellyfish seasons and areas[18,19].

Furthermore, changing pressures is unavoidable when diving, whether it would be breath-hold diving or scuba diving. The dangers from this come in the form of barotraumas to different air spaces of the body and equipment as previously mentioned. Changing pressure also causes changes in the partial pressures of the gases, and with the repetitive nature of free diving, it has been observed to cause symptoms consistent with neurological decompression illness, also known as *'Taravara Syndrome"*[15,20]. The pathophysiology of the disease is yet to be fully understood but it is believed to be the result of a venous gas emboli formation, rather than supersaturation, and accumulation of nitrogen in scuba diving. This might not be a big problem in recreational free divers but may pose a concern for competitive and commercial divers and might possibly require a fitness to dive exam for these extreme divers—a question still unanswered.

Risk Mitigation and Safe Practices in Breath-hold Diving

Breath-hold diving offers a unique way to connect with the underwater world, but carries inherent risks as described in the article. Therefore, safety practices are essential for breath-hold divers. The buddy system is a cornerstone in safe diving. Two divers take turns diving and observing each other. A buddy watches from the surface, particularly during ascent and the critical 30 seconds after surfacing, when blackouts are most likely. Diving alone significantly increases the risk of death, even for experienced divers. Breath-hold divers must avoid high-risk behaviors, particularly hyperventilation, which dangerously reduces carbon dioxide levels, delaying the natural urge to breathe and increasing the likelihood of blackout[21]. Similarly, pushing depth or time limits, diving while fatigued, or ignoring physical discomfort (like ear or sinus pain) are discouraged. Situational awareness is vital. This includes recognizing changing ocean conditions, knowing one's physical and mental state before diving, and constantly evaluating surroundings for environmental hazards. Proper equipment is another key to safety. Low-volume masks, long-blade fins, quick-release weight belts, and a brightly colored surface buoy indicating "Diver Below" increase visibility to boats and provides a rest point between dives[7]. In deeper dives, a freediving lanyard and bottom line with depth markers can enhance safety and orientation. Physical and mental preparedness is important for breath-hold divers. Regular cardiovascular and CO_2 tolerance training, along with relaxation techniques like diaphragmatic breathing, helps optimize breath-hold duration and oxygen consumption underwater. A good level of physical fitness and proper equalization technique help prevent barotrauma. Lastly, it is recommended that anyone interested in breath-hold diving should receive some form of basic training before going underwater[22,23].

Summary

In summary, the breath-hold diving population and community is on the rise. People are becoming increasingly interested in this type of diving, as it brings them closer to underwater world without the need for certification for those wanting to practice it recreationally. It is important that these divers are aware of the dangers and changes that can occur to their body, which might lead to injuries or even disabilities. The important message of this article is to raise awareness among newcomers to this sport/recreational activity, and to encourage them to enjoy it safely. Finally, a recommendation for both new and experienced divers is to dive within the body's limit, never overestimate one's ability, and to always be aware of the surrounding environment.

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