DAN Begins Reporting on Incident Collection of Breath-Hold Diving

The Categories of Breath-Hold Diving

Breath-hold diving is an in-water activity that exists in an occasionally difficult-to-define realm between swimming and compressed-gas diving. The awkwardness comes from the fact that "breath-hold" is an arbitrary name for the activity, since the actual holding of breath is not obligatory: the label is based on the perceived potential for breath-hold. For definitional purposes, the label is assigned when some diving equipment is used, typically a mask, possibly in some combination with a protective suit, weight belt and/or fin(s). Unlike the case for scuba diving, this equipment is used with no breathing gas supply other than ambient air.

Several categories of breath-hold diving exist, including snorkeling, freediving and spearfishing / gaming. Snorkeling is the broadest category. This includes anyone wearing mask, snorkel and fins (but no compressed air supply) in the water. Snorkelers may remain exclusively on the surface and never breath-hold or conduct breath-hold dives as part of their normal activity. Freedivers typically wear a mask and some form of fin or fins and may descend to substantial depths while breath-holding. The nature of the dives will vary dramatically with the individual skill and goals of participants. Competitive freediving includes four events, two well-suited to pool environments and two generally conducted in open water.

- Static apnea is the simplest: immersed, resting breath-hold with no travel.
- Dynamic apnea requires horizontal distance swimming in shallow water during breath-hold.
- Constant-weight involves vertical swimming, with descent and ascent along a shot line while wearing an unchanging amount of weight.
- No limits involves vertical travel with weighted descent and buoyant ascent.

Spearfishing/gaming incorporates the act of underwater hunting for food into the breath-hold exercise. Maximizing depth is generally not the primary motivator. Pool breath-hold is conducted as a training activity, with the primary focus on improving breath-hold time rather than increasing maximal depth. Participants may practice a variety of techniques, including relaxation and voluntary hyperventilation, to increase performance in a relatively controlled setting.

DAN has maintained a dive incident database since 1987. While breath-hold incidents fall outside the original purview of the database, some cases have been reported to DAN since 1994. The 2005 DAN Annual Report on Decompression Illness, Diving Fatalities and Project Dive Exploration provides the first review of the available breath-hold incident data. In the future, breath-hold incidents will be investigated like other diving incidents.

The purpose of incident data collection and analysis is not to assign blame but to learn from past events. Some accidents are just that: unfortunate events that can occur even when sound experience, planning, equipment and support are in place. These cases serve as a reminder of the fundamental risks and remind us to take as much care as we can in all things. Other accidents arise from problems that can be corrected -problems with equipment maintenance, equipment use, training, or procedures. These cases may demonstrate the necessity to make changes that can reduce the risk for all participants in the future. One of the challenges of accident reviews is that the facts are rarely all known. A substantial amount of deductive reasoning, and occasionally some educated guesswork, is required to interpret events.

One-hundred-forty-five cases spanning a period from 1994-2004 were included in the 2005 review. Comprehensive records were rarely available. Virtually all of the reported cases (98 percent, n=142) involved fatalities. Categorical descriptions of the primary activity of the incident victim were available in 67 percent of the cases (n=97). Figure 1 summarizes the known cases. The relatively generic descriptors of "snorkeling" and "recreational freediving" were used in more than 60 percent of the cases with data.

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Major Contributing Factors in Deaths

The cause of death frequently reported for both scuba diving and breath-hold diving accidents is drowning. Unfortunately, it is typical for very little to be known about the contributing factors that lead to this endpoint. When the available data are incomplete, only the major contributing factors may be obvious. Remember that a host of more subtle factors may also have been involved. If you are a breath-hold diver, an effective way to benefit from accident reviews is to fit the scenarios to your practices, visualize the progression of your dives, and to try to identify – and correct – all of the elements that may increase your risk. Major contributing factors were established in only 24 percent (n=34) of the breath-hold cases on file. This is because most of the available records were limited to a preliminary announcement of the accident. Despite incomplete data, reviewers were able to identify several hazard patterns.

Entanglement

Entanglement involved kelp, spearfishing line, and anchor lines. Breath-hold divers have very little time to extricate themselves from entanglement or obstruction before the most modest dive can become fatal. Care must be taken in selecting equipment to be used and deciding when breath-hold procedures are appropriate. For example, using pole spears or other devices that do not employ long lines has a safety advantage in spearfishing. Similarly, breath-hold diving to clear a stuck anchor can be quite hazardous, particularly in rough seas or in depths that approach the limits of the diver. Familiarity with the underwater site will increase safety in all cases. Diver-Boat Interactions: Several cases involved boat strikes while breath-hold divers were on the surface. In some cases, dive flags and surface watchers were present. Surfacing is clearly a significant risk, especially when near high-traffic areas. Bright-colored garments worn by the divers and dive flags positioned in the immediate proximity of divers can increase the chance of catching the attention of passing boaters.

Diver-Animal Interactions

A jellyfish was involved in one fatal incident. Shark attacks resulted in both fatal and non-fatal incidents. Sharks are likely to be attracted to breath-hold divers who are spearfishing. In some cases it may also be speculated as to whether the diver was mistaken for more typical prey, such as a seal. Even if brightly colored suits do not create a "hands-off" label for sharks, they should make the breath-hold diver more visible on the surface. Speared fish should be removed from the water as soon as possible and never carried or attached to the diver while in the water.

Solo / Inadequately Supported Activities

Fatal cases were reported for solo breath-hold divers in pool, freshwater spring and ocean environments. It

is likely that the presence of another person would have changed the outcome in at least some of these cases. Adequate safety in clear water may be maintained by two breath-hold divers if the pair alternate diving and standby roles (the "one-up, one-down" buddy system) and the maximum water depth at the site is well within the limits of both divers. The safety system necessary for protection during more extreme exposures is extensive and requires an organized and dedicated group structure.

Behavioral Errors: Drugs & Alcohol

The use of agents that may compromise mental acuity and/or physical performance introduces a significant risk factor. Alcohol ingestion preceded at least two of the fatal cases on record. Although the true impact of the alcohol cannot be determined, it is possible that it affected decisions or performance that ultimately contributed to the accidents. Excessive Hyperventilation & HLOC. A more elusive behavioral error involves excessive hyperventilation prior to breath-hold diving. Hyperventilation can dramatically decrease the partial pressure of carbon dioxide in the blood. Since carbon dioxide is the primary trigger for inspiratory drive, the urge to breathe is delayed until normal blood levels are restored. This translates into longer breath-hold times.

Hyperventilation, however, increases the body's oxygen stores only slightly. Longer breath-hold times will result in the oxygen partial pressure in the blood falling below normal (hypoxia). Problematically, hypoxia provides a surprisingly weak trigger for the inspiratory drive. A diver who hyperventilates too much may fall unconscious due to hypoxia without ever being aware of an urge to breathe. This is known as hypoxic loss of consciousness, or HLOC.

Shallow-Water Blackout

A further complication of breath-hold diving to depth is that the increased pressure with depth compresses the gas in the lung, effectively increasing the partial pressure of oxygen in the blood. The problem during breath-hold diving is the reversal of the effect as the diver surfaces. As the ambient pressure is decreased, the oxygen partial pressure is reduced much more quickly than by consumption alone. Unconsciousness can develop rapidly in the final part of the ascent, when the relative rate of pressure decrease is greatest. This phenomenon is referred to as shallow-water blackout. Breath-hold divers who choose to use hyperventilation will generally experiment to try to predict their personal safe limits.

However, if used too aggressively, even small increases in dive depth, exertion or breath-hold duration can produce a very hazardous situation. Excessive hyperventilation contributing to HLOC or shallow-water blackout may represent the major contributing factor in many of the breath-hold fatalities with no other apparent explanation. This is very difficult to document in most cases, but this is a risk that can clearly be reduced by conscious choice.

Failing to Ditch Weights

The final behavioral error discussed here is the failure to ditch a weight belt when appropriate. There are several cases of fatality victims found with weight belts still in place. It is difficult in most cases to know whether hypoxia impaired the ability to respond, or whether panic was a factor. At least one case, though, highlights a lack of thought during a stressful event. An exhausted breath-hold diver was still wearing his weight belt when help arrived at his surface position. The victim described his condition immediately prior to rescue as impending blackout. Ditching the belt at any point in the development of this incident would probably have been an effective self-rescue.

Equipment Problems

At least one breath-hold diver was observed to fall unconscious as he neared the surface during ascent

(presumably a case of shallow-water blackout). He quickly sank beyond the point at which those on the surface could reach him. Weighting during breath-hold diving is often considered from the point of view of optimizing performance, but the more important consideration of weighting is for safety. A breath-hold diver should be slightly positively buoyant close to the surface; this helps to minimize the risk of sinking in case a problem develops in shallow water.

Impaired Health And Fitness

The available records contain several cases involving cardiac compromise, three involving seizure and at least one involving inadequate fitness that resulted in a double fatality. The demands of breath-hold diving can be significant, particularly in open water, where rough water or currents may have to be overcome. Inadequate fitness reserves or other health problems may leave breath-hold divers unable to cope with normal challenges that can arise.

Summary

While a small number of high-profile fatality cases may be widely reported, limited information is available for most breath-hold accidents. Non-fatal incidents are rarely reported. Data from both fatal and non-fatal cases would provide valuable information to improve awareness, facilitate training and promote procedural evaluations. DAN will follow up breath-hold incidents in a manner consistent with other diving incidents in the future.

Quick Definitons

Hyperventilation: Exchanging gas between the lung and the atmosphere at a rate faster than required by the metabolic demands of the body. This may be accomplished by breathing faster and/or deeper than required. The primary effect is to remove carbon dioxide from the body. Carbon dioxide is the agent that serves as the primary trigger for the breathing cycle. Reducing the amount of carbon dioxide in the body prior to breath-hold will delay the urge to breathe.

Hypoxic Loss of Consciousness (HLOC): Loss of consciousness arising from hypoxia.
Note: excessive hyperventilation can result in HLOC without warning.

Shallow-Water Blackout: Loss of consciousness arising from the rapid reduction of the partial pressure of oxygen in the blood as the ambient pressure decreases during ascent. Hyperventilation can make shallow-water blackout more likely, by increasing the breath-hold time.
Note: shallow water blackout will often occur at or just beneath the surface during ascent. A negatively buoyant diver may sink without warning after reaching the surface.