Fitness & Physiology

Cold Stress Complicates Decompression Risks

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Most scuba divers would probably recognize thermal stress as a risk factor in diving. However, due to the way thermal stress is portrayed in diving texts, many probably think that hypothermia is the only hazard. Hypothermia, however, is only part of the story.

The diving environment holds many conditions that can lead to the development of hypothermia, particularly in less-than-tropical waters.

Here are a few scenarios: A lost diver could become separated from a dive boat and spend a long time floating on the surface, awaiting pick-up. An uncovered dive boat breaks down while returning from a dive site under less than ideal conditions. An extremely long-duration scientific or technical dive is conducted.

While the possibility of developing hypothermia exists in diving, it would be an exceptionally bad day for the average diver—recreational, scientific or commercial—to encounter a substantial risk. The available protective equipment effectively copes with normal circumstances. Generally, dives end by choice or due to air supply limitations before hypothermia becomes a real problem.

More subtle, and potentially more important to general diving safety, is the way in which a diver's thermal status can influence decompression risk.

The first important clarification is the difference between thermal status and environmental conditions. Divers operating in an extreme environment may be more likely to experience greater
thermal stress, but they can avoid such stress if they are adequately protected.

The thermal status (and thermally induced risk) of the diver will be influenced by protective clothing, pre-dive, during-dive and post-dive activity, and an individual's nature—i.e., body shape, body composition. These factors must be kept in mind when evaluating individual cases.

Every diver learns that inert gases—e.g., nitrogen and helium—are absorbed at increasing rates with increasing depth. Every diver is also familiar with some form of dive table and/or dive computer developed to ensure safe dive profiles.

What is often less clearly understood is that a diver's thermal status can substantially alter inert gas exchange, and that changing the inert gas uptake and elimination ultimately affects the decompression requirement for any given exposure. A dive that is safe under one set of conditions may lead to decompression illness in another.

Common misconceptions about thermal status include an expectation of the power of dive computers. First, even though dive computers may display temperature, they do not incorporate temperature measurements into the mathematical model computing decompression. Second, even if they did, they would be basing the input on the surrounding temperature and not the critical element—the thermal status of the diver.

A classic field study demonstrated the ability of thermal stress to affect inert gas uptake. Participants repeated dives in both properly fitting, and in extremely ill-fitting, wetsuits in the 50°F / 10°C ocean waters off Vancouver Island, British Columbia (1). Using Doppler ultrasound following the dives, researchers measured the presence and concentration of gas bubbles circulating in the blood. They observed fewer bubbles following cold dives. They concluded that when a diver is cold from the start of a dive, vasodilation restricts blood flow to the extremities and total gas uptake is reduced. A lowered inert gas uptake reduces the amount present at the end of the dive.

The theoretical benefits of reducing inert gas loading will be appreciated by most divers. Few, however, will be willing to spend a dive being miserable to gain the benefit. Practically speaking, many cold-water divers actively try to store extra heat before a dive to postpone the chill. This may include pre-heating in a warm room while suiting up or pouring hot water in their dive mitts before they enter the water. These practices cause an increase in tissue temperature. Warmer tissue will be better perfused (i.e., receive more blood). With maximal inert-gas uptake generally occurring during the earliest (and usually the deepest) portion of the dive, such behaviors can substantially increase gas uptake. Ultimately, this may affect the decompression requirement of a given dive.

Despite pre-dive warming strategies, a growing chill will develop as a cold-water dive continues. In many cases, the cold stress may be substantial toward the end of the dive. Under these conditions, extremity circulation may be dramatically reduced. The hands that were so well perfused at the start of the dive may be effectively isolated by the time the diver returns to the surface. Without adequate perfusion, inert gases could not be removed from the tissues of the body's extremities to the blood, and then to the lungs.

If inert gas is not removed from a region, a greater risk of local supersaturation and bubble formation exists. Even if bubbles do not initially form spontaneously, the “risk window”—the period of time when the risk of experiencing complications from decompression increases—is prolonged. This was observed somewhat accidentally in a study of cold stress following diving exposure. Following a cold exposure coupled with a dive, three of four participants developed symptoms of skin bends when taking showers long after the normal risk period expected from the dive had passed (2).

Getting into a shower or hot tub after a cold dive may sound like a wonderful method of warming up, but it can be problematic. The rapid warming of cool tissue may create problems before the extremity blood flow is increased and excess inert gas can be removed. The additional complication is that gas solubility is inversely related to temperature. Warming a nearly saturated tissue may be enough to induce bubble formation and increase the risk of developing decompression illness.

While we made the point that it is the diver's thermal status...
that is critical, not the environmental conditions, the ambient conditions will generally influence what the diver experiences. A study correlating climatic and environmental factors coinciding with decompression treatment records in Great Britain demonstrated this in a novel manner (3). Controlling for as many factors as possible, the investigator documented an increased rate of decompression illness associated with days on record with lower air temperatures and higher wind chill factors.

We want to emphasize that this article does not seek to discourage cold-water diving. Its intent is to help divers appreciate some of the more subtle factors of inert gas kinetics, and evaluate diving safety in light of these effects. Eliminating the risk of injury is generally not practical, but making it as low as possible is a worthwhile goal.

Practically speaking, several strategies may reduce decompression risk when you're diving in conditions of elevated cold stress:

- Plan dives to be more conservative. Reducing in-water times will decrease the cold stress experienced. Shorter and/or shallower dives will reduce the decompression stress for any exposure. Remember that the standard U.S. Navy dive table rule for cold dives is to calculate repetitive groups and time limits with the next greatest depth AND the next greater bottom time.

- Implement longer safety stops as an inexpensive form of insurance. Light exercise during the ascent and safety-stop phases may assist in maintaining peripheral blood flow and increasing breathing rate and inert gas removal. It may also keep you from becoming more chilled. Do limit the activity to light exercise. Vigorous exercise could work against your goal by stimulating bubble formation.

- To reduce the risk of complications, minimize post-dive exertion. Remember that this caution period should be extended relative to that following a neutral or warm dive.

- Be conservative with practices for pre-dive warming. Start dives warm but try to not exaggerate peripheral circulation.

- Be conservative and delay active efforts at post-dive warming. Think about the warm shower, but choose the merits of anticipation over instant gratification.

Divers should appreciate the influence of thermal status on decompression safety. Understanding the risks and implications improves your ability to make the best choices regarding your diving health.

REFERENCES


