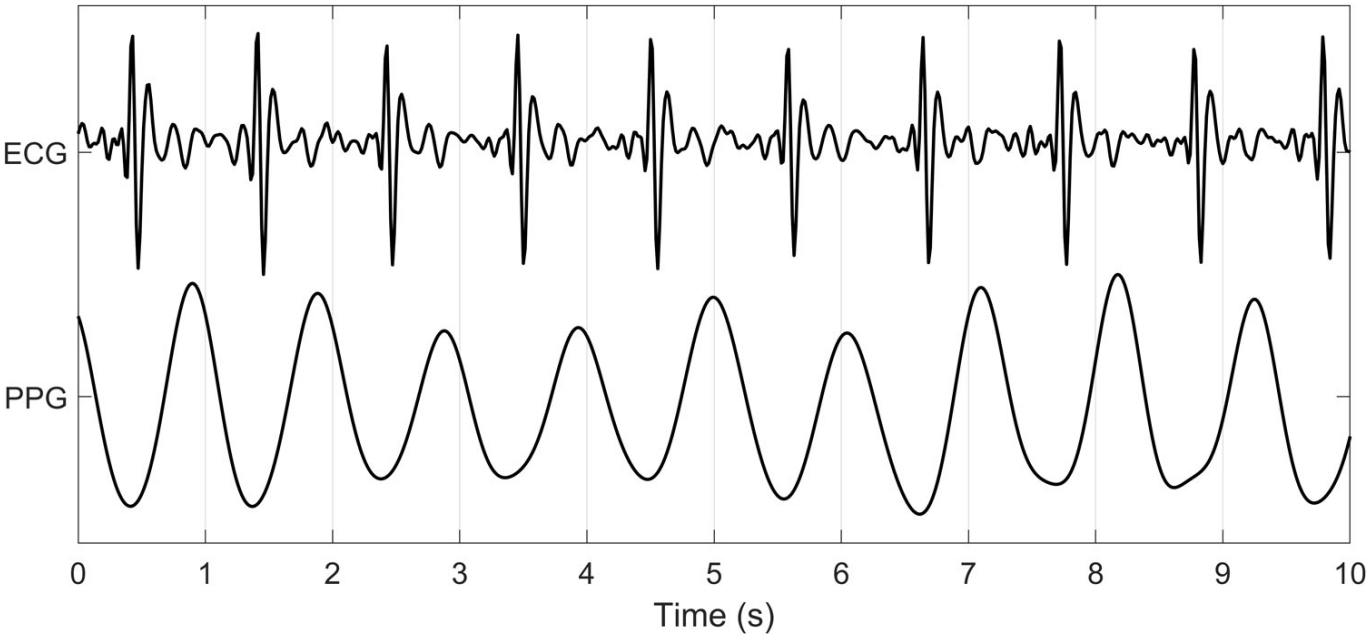
How close are we to the next big step in diver safety?

Underwater biomonitoring is increasingly regarded as a key next step in advancing decompression safety for divers. In line with this trend, several models of dive computers with integrated smart watch features, such as pulse and blood oxygen monitoring, have entered the market. The hopes invested in such technologies, and the obstacles faced by them, have been detailed here in Alert Diver, as well as in InDepth magazine.

Pioneering research in the field conducted under the auspices of DAN Europe was presented by Prof. Alessandro Marroni at Rebreather Forum 4 in 2023 (see RF4 Proceedings, pp. 206 ff). The researchers' goal is to collect biometric data during dives, relate it to DAN's extensive research database of over 130,000 dive profiles, and come up with an approach to integrating dive computers with underwater biomonitoring for a more proactive approach to decompression safety and informed decision-making underwater.

Technological challenges

Unfortunately, this effort has been hampered by the limitations of existing devices. When pressure and salinity come into play, collecting high-quality biometric data isn't trivial. Wearables that measure a diver's heartbeat do so only indirectly by means of the pulse, which is a very low-resolution signal compared with a full electrocardiogram (EKG). When it comes to heart-rate variability (HRV) – a suggested biomarker for assessing DCS risk indirectly via inflammatory response – pulse rate variability has been shown to be a poor substitute for true HRV due to inferior signal quality.



ECG and pulse signal by comparison. A true ECG is much more useful in physiological research, in particular when it comes to generating derived values like HRV.

In addition to these and other challenges, there is the question of how to get the data to the surface. The only way to transmit wirelessly from underwater is by using an acoustic modem, which has a very low bandwith – insufficient for live transmission of a full ECG and all the other metrics like breathing rate, blood oxygenation and body temperature.

Therefore, a wearable either needs to have storage capacity for large volumes of raw data for later analysis, or on-edge processing capability to compute less data-intensive, derived values like HRV for live transmission to the surface. Ideally both. This challenge has not been solved to the point where it can be used in large-scale experiments with real divers in the ocean, much less at the consumer level.

The device as worn by the diver

New tech

Tiger Tech Solutions, a Florida-based company focused on biometrics for the US military and several elite sports teams, including college football championship finalists Miami Hurricanes, recently conducted successful tests with a wearable device that measures heart rate and heart rate variability (i.e., a full ECG), breathing rate, oxygen saturation, body temperature, and depth. According to the company, features soon to be integrated include 3D location of the diver and decompression computing based on the Bühlmann algorithm (ZHL-16C).

The engineers at Tiger Tech modified their existing equipment (called the 'Warfighter Monitor' or WFM to reflect its military origin) for underwater use. The WFM is a wallet-sized unit mounted to a strap worn on the diver's upper arm, under the exposure suit. Unlike earlier systems, its sensors work even while immersed in salt water. The capability to compute derived data is already implemented and inherited from the military precursor.

The underwater version of the WFM is in the advanced prototyping stage and has undergone several successful tests in which a full ECG, as well as oxygen saturation and respiratory rate were captured underwater, with the device being worn under a wetsuit. Its single-limb ECG feature has recently been validated in a peer-reviewed study.

A diver wearing the WFM (on the inside of the left bicep).

It’s personal.

For Joe Wishon, Tiger Tech’s CTO and an avid technical diver himself, this goes beyond business. It’s personal: “I’ve been severely bent myself, and I can tell you it’s no fun. It happened while I was still underwater. Maybe there were precursor signs in my vitals that could have predicted the bend before it happened, maybe not. We won’t know unless we figure out a way to measure and analyze the data.”

Asked about the engineering challenges his team needed to overcome, he laughs. “There were a few. At present, there is no commercially available wearable device that can do a full ECG with heart rate and HRV, measure respiration rate, body temperature, and oxygen saturation underwater.

The first challenge was to get clean data. We already had a proven wearable, which has been extensively validated in the academic literature. But we had to modify it for underwater use. We had to waterproof our sensors, ensure stability under pressure, and develop new noise filtering algorithms to eliminate interference created by diver movement and environmental factors. Building sensors that are both hydrophobic and electrically conductive has been a bit tricky, to put it carefully.

Then we had to bring everything together in a single device that can survive the underwater environment, run efficiently on battery power, and keep all the sensors in sync. The system has to handle pressure, manage heat, and keep collecting accurate data throughout long dives. We designed a compact, pressure-resistant housing and wrote custom firmware that controls when and how each sensor collects data to save power while keeping the data secure.”

DAN Research and Tiger Tech join forces

Over the years, researchers at DAN Europe have compiled an extensive database of 130,000 dive profiles with associated physiological and epidemiological data. DAN aims to correlate this data with real-time biometrics collected during dives and has been working on its own monitoring solution to this end.

The combination of DAN's expertise in decompression research with Tiger Tech's expertise in sensor technology is too good an opportunity to pass up. The two organizations have therefore decided to form a partnership and conduct research together.

"We want to equip divers with a high-quality sensor system that captures live ECG, respiration, and oxygen saturation," says Joe Wishon, CTO of Tiger Tech Solutions. "This will enable us to gain a better understanding of how these biometrics change while diving, correlate this information with DAN's database, and deliver a device that gives divers live feedback on DCS risk and other health conditions, well beyond what existing wearables are capable of."

DAN's long-term project

Prof. Alessandro Marroni, President of DAN Europe, adds: "At DAN Europe, we have been working since 1993 to achieve reliable epidemiological data about the risk for decompression illness and the best ways to prevent it. Over the recent 10 years, we have also intensively investigated patho-physiological changes in divers, initially before and after the dive, more recently with prototype real time physiological monitoring during the dive.

This basic and field research action has led to unique knowledge about the individual risk, based on epidemiological data, allowing any diver to calibrate and select a 'preferred' risk level. The recently

acquired data showing real time physiological response to diving and decompression stress, although in controlled experimental conditions, opened a new door toward real-time personalized dive safety.

Combining this with a rugged and reliable real-time physiological monitoring system compatible with real-life diving exposure is the current goal!”

It’s the dawn of a new… well, not so fast.

These goals are ambitious, and even though the project holds great promise for improving the safety of divers, only research will show to what extent such expectations are realistic.The WFM may afford scientists opportunities to test plausible hypotheses about the correlation between decompression risk and certain physiological parameters that they haven’t been able to test before. As with any test, the outcome isn’t a foregone conclusion.

It would therefore be premature to say that the next great advancement in decompression safety is around the corner. However, it may have come a big step closer. Stay tuned!