Latests findings on DCI and Dive Physiology (Part 2)

Following the first article, published last month, we keep presenting the research findings which came out from "The Science of Diving", final conference of the scientific project named PHYPODE**.**
One further assumption was that the vascular **endothelium**, the inner layer of all blood vessels, played a key role in DCS.
F. Guerrero (Laboratoire Optimisation des Régulations Physiologiques – ORPhy-, University of Brest, France) investigated post-dive altered endothelial function.
In general, the vascular endothelium regulates vascular activity and cardiovascular health by releasing substances that regulate many functions, such as blood flow, inflammation, thrombosis, oxidative stress, and so forth. Increased endothelial permeability – contact loss among microvascular endothelial cells and weakening of their adhesion to the basement membrane – is commonly involved in DCS. It was found that each dive lowers the vasodilatation of every vessel as shown by flow mediated dilation (FMD) measurements. Large vessels as well as microvessels, i.e. the capillary network and place of gas exchange, are impaired after diving and are modified even more after DCS. Research on breath-hold divers (who develop no bubbles) suggested hydrostatic pressure and hyperoxia to have this destructive effect on the endothelium, due to the oxidative stress it creates and the endothelial cell death it triggers. Since there are also severe DCS cases with no alteration, it can be concluded that it is not the endothelium itself that plays the key role but the circulating factors that derive from it. One of them is nitric-oxide (NO) which is produced by the endothelium. By blocking NO in animal studies, the researchers found gender-related differences: DCS occurrence increased in females but not in males. This is where future research will look at – the gender differences of the DCS mechanism.

As known, oxygen is an important gas in diving, and breathing pure oxygen is a common and effective first emergency treatment for DCS. However, **oxygen has also negative effects**. Research in the field was conducted by J. Kot (National Centre for Hyperbaric Medicine, Medical University of Gdansk, Poland). Oxidative stress is caused by the destructive effect of free radicals (O2, H2O2, OH) which are created during an incomplete reduction of oxygen in the cell. These radicals are aggressive and short-acting molecules that destroy DNA, protein and lipid molecules. Fortunately, the human body possesses an antioxidant defense system to manage the balance between antioxidants and radicals and control the damage. The highest partial pressure of oxygen is in the lungs, which serve as a first-line defense system. The destructive effect can lead to fibrosis of the lung tissue. If this happens, patients can suffer from hypoxia even though they are breathing pure oxygen. The good news is that this kind of oxidative stress applies more to tec-divers who are using oxygen mixes than to the majority of recreational scuba divers who are using, e.g., Nitrox.

PHYPODE'S research suggests that there is obviously an individual susceptibility to DCS, as shown by findings like easy shunters, high-grade bubblers, divers with differing endothelium quality, genetic predisposition, and so forth. As written above, a good way to lower the risk of DCS is preconditioning. Another possibility is to develop new dive technology and implement a revised and more complex decompression model which integrates personalized medical as well as real-time dive information.

The concept of the **"Bionic Diver"** was born a few years ago and is based on new decompression algorithm considerations (physiological parameter-based algorithm adaptation) that will incorporate 24-hour medical monitoring of physiological parameters like heart rate, body mass index (BMI), and other personal information. The aim is to develop an individually adjustable dive computer which tailors

decompression schedules specifically to the physiology of the diver, in real-time, and accounts for hydration, fatigue and a variety of other conditions showing how the human body responds to dive stress.

At present, MARES is testing a modified Icon HD dive computer with a powerful processor and color display. It can collect pre, during and post dive information, recognize signs of nitrogen narcosis, conduct decompression calculations etc. Current developments were presented by G. Distefano (Product Manager at MARES, Genoa, Italy).

As measuring human physiological parameters has become one of the main objectives in dive research, the options a **rebreather** device can offer were explained by N. Donda.
A rebreather breathing apparatus recycles exhaled gas which is purified from carbondioxide (CO2) through a closed circuit consisting of several elements, and reinstates the amount of oxygen (O2) that the body has metabolized. Since the rebreather keeps the exhaled gas within the closed circuit, it can be used to collect data of human physiology during diving. Researchers decided to install various sensors for measuring the quality and amount of gas inhaled and exhaled in the different air spaces that can be found in the device. The monitored parameters included the quantity of oxygen inhaled/exhaled, the quantity of CO2 exhaled, respiratory rate, total volume of breathing gas, gas temperature breathed in and out, and humidity level in the inspired gas. Other parameters monitored were depth (pressure), dive time, position underwater, frequency of fin kicks, heart rate, and speed of descent and ascent of the diver. Sensor reliability was tested and values were converted into usable data which were either electrically or wirelessly transferred to a storage unit with adequate memory.

Diving medicine is advancing, and there are new findings about mechanisms of decompression. So far and due to the lack of appropriate sensing technology, physiological data of the diver were only gathered in laboratory or pre-and post-dive situations, but never during a dive. Arne Sieber (Research Scientist at IMEGO AB, Gothenburg, Sweden) developed new sensor technologies to monitor **ECG and body temperature** during immersion. Data about the metabolism of the diver were gathered with a closed circuit rebreather, where oxygen, CO2, breathing rate, tidal volume, respiratory minute volume and blood pressure could be measured.
The core component of this bionic or digital diver approach will be a new dive computer with a wireless interface to which various sensors can be connected and which has a powerful microprocessor which is able to perform comprehensive decompression calculations. This system is momentarily used for military purposes only, but will soon be available for the broader public in all kinds of systems.

In summary, the PHYPODE research project has brought an extraordinary high amount of quality data in form of detailed knowledge as well as proof of many habits divers have intuitively, but don’t know why. Precise mechanisms and measurements have been investigated, tested and solved and can now lead to the development of a safer decompression model implemented in a personalized dive computer, integrating several physiological real-time parameters with other medical information. These four years of intense research may have been hard work, but they definitely contributed to the development of dive technology, a great step forward towards improved dive safety. They have also cleared the path for future research by raising new questions while closing others.

At the conference, the project leaders took the opportunity to present the book **“The Science of Diving, Things your instructor never told you”**, a comprehensive compilation of the current concepts and ideas, as well as the results of this cutting-edge research. With its 273 pages in 11 chapters, the book is an excellent guide for anyone involved or interested in diving, such as medical officers, hyperbaric chamber personnel, scientists, dive professionals, dive operators, and dive students. Avoiding scientific jargon and using vivid language, the book enhances understanding even the most sophisticated parts of science.

The book was edited by Professor Balestra and Dr. Germonpré, co-edited by M. Rozloznik, P. Buzzacott and D. Madden from the European Underwater and Baromedical Society (EUBS), and written by each of the 14 PHYPODE researchers.

Featured publication

“The Science of Diving, Things your instructor never told you”
Published by Lambert Academic Publishing, it can be purchased online here, or can be ordered via any bookstore using ISBN number 978-3-659-66233-1. The book is sold at 49.90 €, and all royalties from the sales are donated to EUBS, to promote further diving medicine research.

Educational Resources: a DAN Membership Benefit
DAN Members regularly receive information about and are invited to interesting conferences, seminars and events focusing on diving safety. Discounts on the entrance fee or free participation in such events is just one of the several DAN Membership benefits.
To keep you up to date with events similar to the PHYPODE conference, please register on the DAN Europe website. You will regularly receive our newsletters, and valuable information about first-aid training opportunities, dive insurance plans, online webinars, and much more.