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2021 Divers Alert Network Research Intern

Our World Underwater Scholarship Society Intern

Hydration in Diving / DAN Internship

Background

The hydration status of SCUBA divers has long been a topic of interest amongst researchers in the field. Water is necessary for the homeostatic balance of life. The body has many ways of dealing with changes in hydration status. Various negative feedback loops are constantly at work influencing the excretion and retention of water. Our body is composed mainly of water, and it is a crucial ingredient in physiological functions around the body.

SCUBA diving is an extreme sport that puts a person in an environment where optimum performance can significantly mitigate risks. Dehydration puts the body under stress and can lead to hyperthermia, decreased cardiac output, decreased blood pressure, impaired cognitive performance, chronic diseases, stroke, etc. (Popkin, D'Anci, Rosenberg, 2010). These problems can become life threatening as a person gets older, especially as potentially compounding chronic diseases become increasingly prevalent. It is generally considered that the diving population is getting older, and with age comes the increased likelihood of developing chronic diseases. When compounded with the stressors of diving in an unknown underwater environment, extreme temperatures of dive sites, and lack of control of available fluids at a dive site, it is clear to see that understanding how diving affects hydration status is imperative to the assessment of the SCUBA diver's health.

One of the main concerns of a SCUBA diver is the formation of venous or arterial gas emboli that are thought to provoke the symptoms of decompression illnesses. As a diver inhales air under pressure, inert gas becomes saturated in the blood and tissues. According to Henry's Law, the greater the total pressure of a liquid, the more gas can be dissolved in that liquid. When the diver begins their ascent, gas comes out of the blood and is exhaled until an equilibrium is reached with ambient pressure. According to Boyle's Law, which states that as pressure decreases, volume increases, if this gas does not have sufficient time to be off gassed by the lungs it will continue to expand upon ascent and bubbles or gas emboli may form as a result. According to a study done on the effects of dehydration on decompression sickness development in a swine model, it is "plausible that dehydration could alter inert gas removal by reducing blood flow to poorly perfused tissues or by decreasing blood surface tension thereby facilitating bubble formation." (Fahlman, Dromsky, 2006). Gas must travel through the blood to reach lung capillaries to be exhaled. If the blood is viscous and unable to circulate through the tissues this gas could become trapped. There is some evidence available that decreasing the surface tension of a liquid will induce bubble formation (Gempp et al., 2009). Water is a liquid with a high surface tension, and an adequately hydrated diver could have blood with a larger proportion of water which may decrease the likelihood of bubbles forming (Gempp et al., 2009).

When the body is immersed in water, blood is shunted to the thorax and away from the extremities (Burki, 1976). The walls of the atria contain mechanoreceptors that are stimulated by stretch, so an increase in thoracic blood volume causes these receptors to fire (Miki, Hayashida, Shiraki, 2002). These receptors decrease afferent sympathetic nerve input to the kidneys which stimulates atrial natriuretic factor release, increases renal blood flow, and suppresses aldosterone and antidiuretic hormone (Miki, Hayashida, Shiraki, 2002). These responses eventually lead to an increase in urine production and a lowering of blood volume and pressure.

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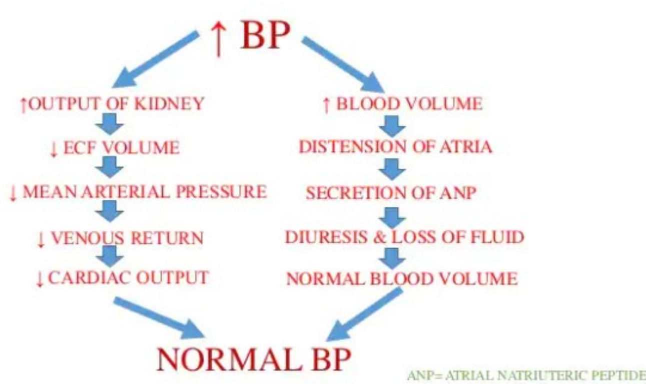


Figure 1: Regulation of blood pressure by renal body fluid mechanism

This feedback loop is important to divers due to the changes in blood distribution during immersion and the responses to counteract this. When a diver is submerged the distribution of blood shifts towards the thoracic cavity which places greater pressure on the heart. Receptors in the walls of the heart are stretched and stimulated which alters autonomic nervous conduction that cause the kidneys to increase urine production. This may be the reason that divers feel the need to urinate frequently during a dive. When urine is excreted, some proportion of the body's water is lost which contributes to the loss of hydration of the diver.

If a diver is already on the verge of dehydration and decides to go diving, these responses could worsen the situation. Given that dehydration has been shown to negatively alter the mental and physical performance of a person, a dehydrated diver could be at risk of reduced performance in an environment where optimum performance can mitigate significant risks. While there is a weak correlation between bubble formation and incidence of DCS, dehydration could lead to bubble formation, and being hydrated entering a dive could reduce the risk of DCS occurring. As a person gets older, the thirst response diminishes (Popkin, D'Anci, Rosenberg, 2010). With an increasing number of elderly divers, it is of concern that they could be entering a dive dehydrated. It is imperative that the effects of hydration on the body and mind are understood in the SCUBA diver to make diving safe for all.

Pilot Study

I conducted a pilot study this summer to see how diving affects the hydration status of SCUBA divers. I collected urine samples from divers for their last void predive and their first void post-dive. I also collected control samples approximately over the same time span during non-diving days to compare to. These samples were collected in sterile, sealed cups (Figure 2) and labelled appropriately. I then stored these samples in a cool, dry location and analyzed them one day post dive or immediately after data collection.

Specific gravity and osmolality are two measurements that can be taken from a urine sample to assess hydration status. Specific gravity is a unitless value measured by dividing the density of a sample by the density of water. Density has units of grams per cubic centimeter and is a value used to tell how much mass is located within a certain area of a substance. Water has a density of 1 g/cm^3 meaning there is 1 gram of water per cubic centimeter of space it occupies. The greater the density of a substance, the more mass is located within some area. A urine sample with a higher density and specific gravity indicates a higher content of formed substances and less water. This is likely due to the person the sample was taken from being dehydrated. Specific gravity was measured by placing a few drops of a sample on the ATC analyzer (Figure 4) and reading the specific gravity on the window (Figure 5). Osmolality is a measurement with units of milliosmoles per kilogram of water and is used to tell how many dissolved particles are in a solution. The higher the osmolality of a urine sample, the more dissolved particles are in the sample. This is also likely due to the person the sample was taken from being dehydrated. Osmolality was measured by calibrating an Osmocheck analyzer (Figure 3) and then placing a few drops of a sample on the window and hitting start.

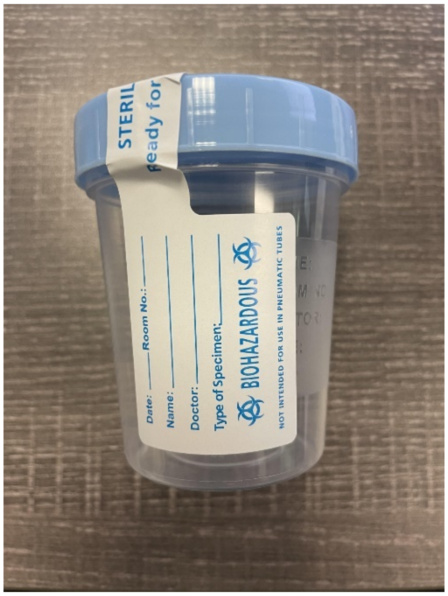


Figure 2: Urine collection cup

Figure 3: Osmocheck analyzer

Figure 4: ATC specific gravity analyzer

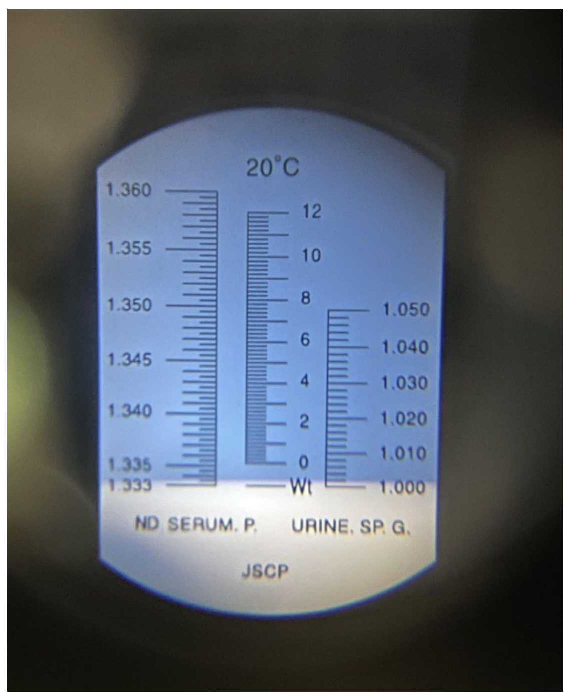


Figure 5: Specific gravity analyzer window

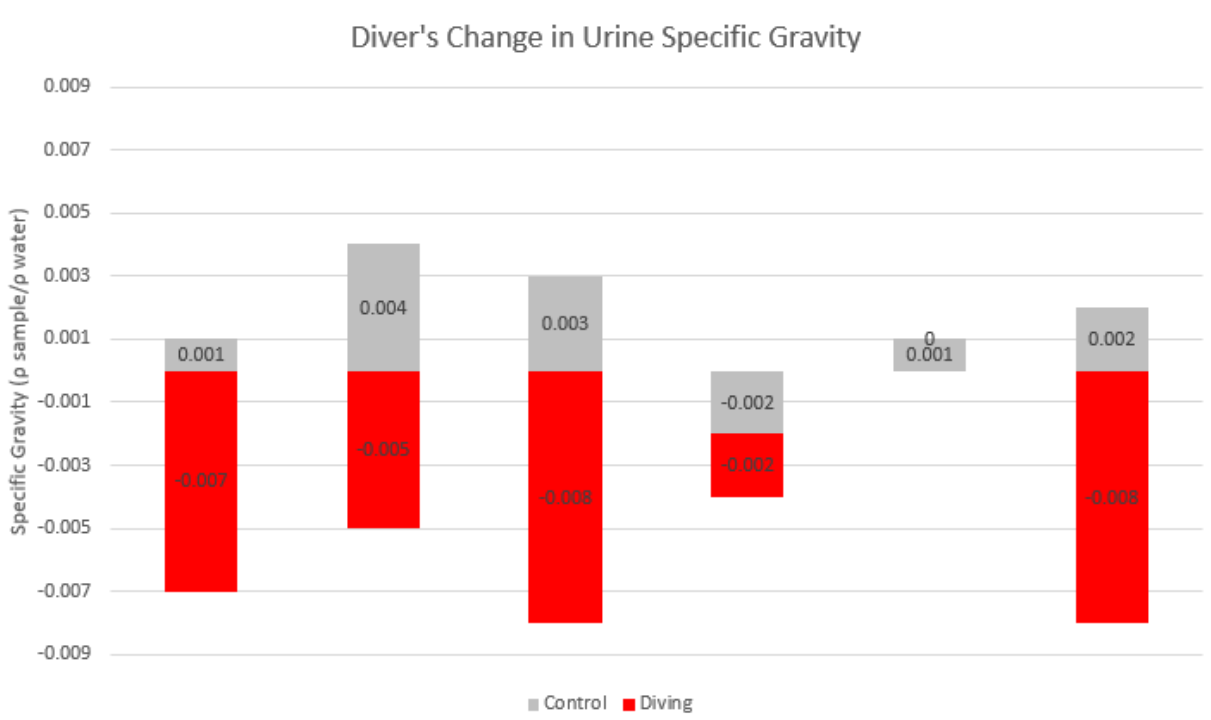


Figure 6: Change in diver's urine specific gravity around a dive versus around a non-diving timeframe.

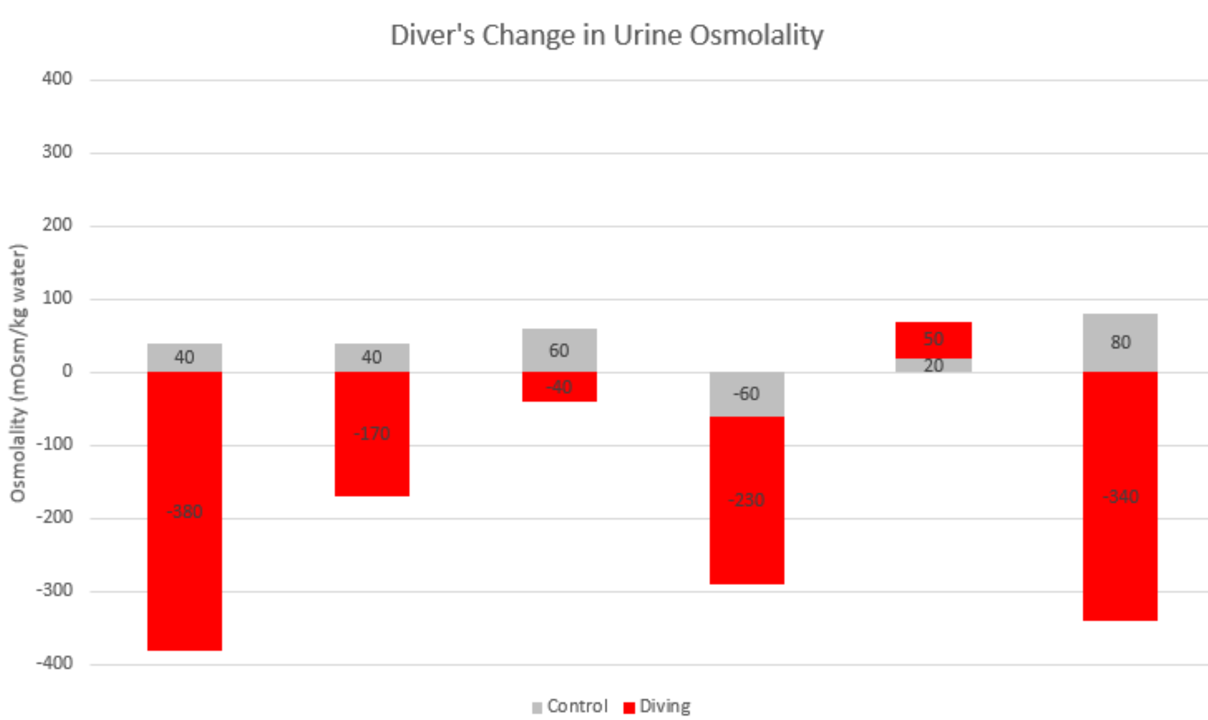
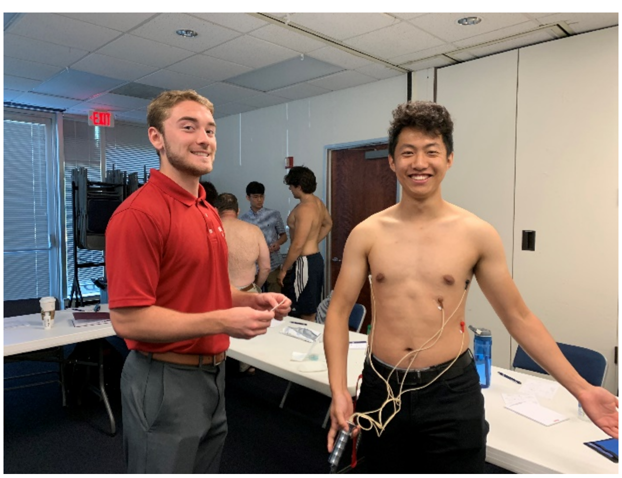


Figure 7: Change in diver's urine osmolality around a dive versus around a non-diving timeframe.

*These results are mainly observational, and no conclusions were drawn from this data.

Field Research Operator Workshop

Before participating in any of our field research events, we held a field research operator workshop where we learned to conduct various tests like trans-thoracic echocardiograms, electrocardiograms, and urine analysis. We learned how sound travels through tissue and is reflected to the ultrasound probe to create an image. David Le, PhD candidate at UNC's SCUBA Lab, demonstrated how microbubbles are used to test Doppler techniques in the lab and how the speed of an object affects the frequency of sound that is reflected from it. Jayne Cleve, ultrasound technician at Duke University Hospital, demonstrated how to analyze cardiac ultrasounds and differentiate between gas emboli and anatomical structures.



Field Research Events

We held many field research events over the summer at Mystery Lake, Fantasy Lake, and Bluestone Quarry. Our main goal at these events was to recruit participants on site, run them through the informed consent process, and conduct various studies on them pre and post dive. One of these studies included our ultrasound comparison study where we used the Vivid Q ultrasound device, Butterfly ultrasound device, and O-dive Doppler device. We used all three of these devices on divers pre dive and for 20-minute increments post dive. We then used these recordings to see if bubble grades were comparable across all three. Another one of our studies included a neurocognitive test where divers took a baseline test and a test post dive to see if the fatigue from diving affected their scores. The last study we did was the hydration study where urine samples were taken from divers pre and post dive and compared to their baselines.

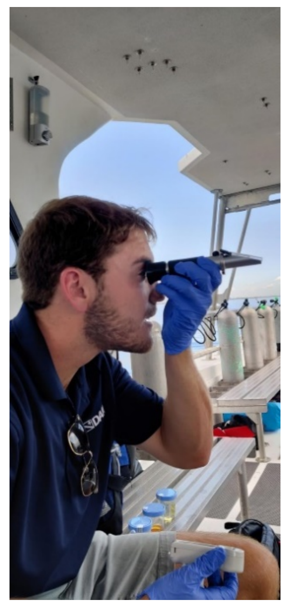
Decompression Workshop Series

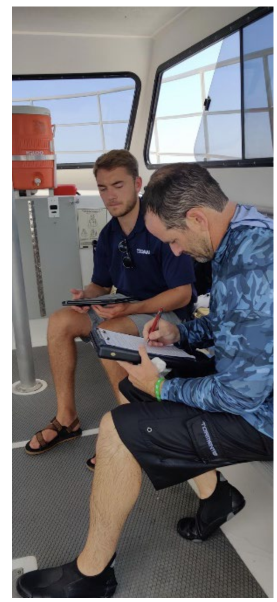
Over the course of the summer, on the first Friday of every month, we held decompression workshop lectures from people locally and around the world. Our first was Peter Buzzacott from Australia who presented on his research on harvester divers where he tracked the relationship between their dive profiles and the prevalence of decompression sickness. He then used this data to build the “SCUBA” package in the statistical software program “R” where dive profiles can be inserted and the pressure of a gas in a theoretical compartment based on gas kinetics is calculated. Our next presenter was Virginie Papadopoulou from UNC who taught us contrast enhanced ultrasound imaging and therapy, analysis of VGE ultrasound images, and biomedical statistics through the software “Graphpad Prism.” Next was Francois Guerrero who presented his work on the heritability of decompression sickness resistance in rats. Finally, we heard Frauke Tillmans from DAN talk about COVID-19 and diving.

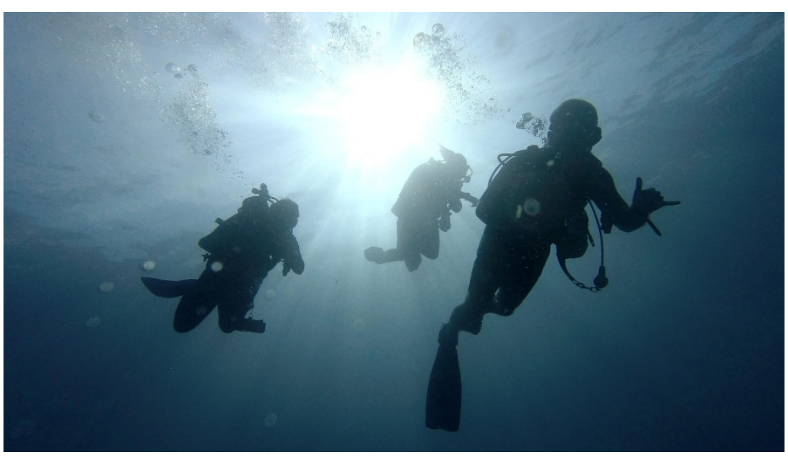
Lobster Mini Season Research Trip

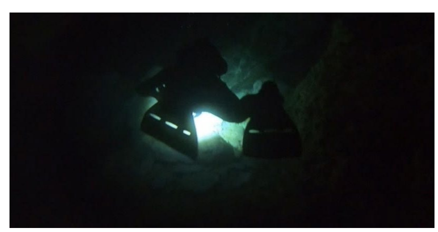
For Lobster Mini Season, the DAN research team went to West Palm Beach, Florida to collect data from the harvesters. We made an initial stop at the Cooper River in South Carolina to dive for prehistoric shark teeth and fossils, and then went to the Georgia Aquarium for a behind the scenes tour of the facility.

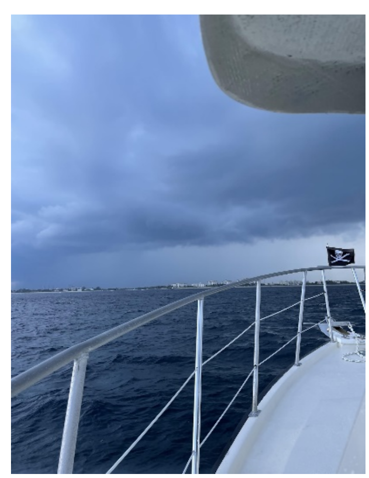
We then made a stop at Blue Grotto in Williston, Florida to dive and do a dress rehearsal to discuss the order of measurements, assign tasks to team members, and make sure the equipment we would be using was working. We then continued onto West Palm Beach and on the first day myself and 3 other interns were on the Pirate’s Obsession Charter. We collected data on 4 lobster divers that day measuring neurocognition, skin conductivity, electrocardiography, subjective fatigue, and urine specific gravity/osmolality before diving, during the surface interval, and post dive. We were also able to dive ourselves and got to see the beautiful reef that the coast had to offer. Although we encountered some difficulties along the way, we managed to obtain good data, debrief for the day, and figure out what we could do differently on the second day. The second day I was on the Pura Vida charter with one other intern. This time we were not diving but we were able to collect data sets from 5 divers and enjoy the beautiful day on the water. On our way back, we made a stop in Lake City, Florida where we toured Dive Rite and got to take an introductory regulator repair course.











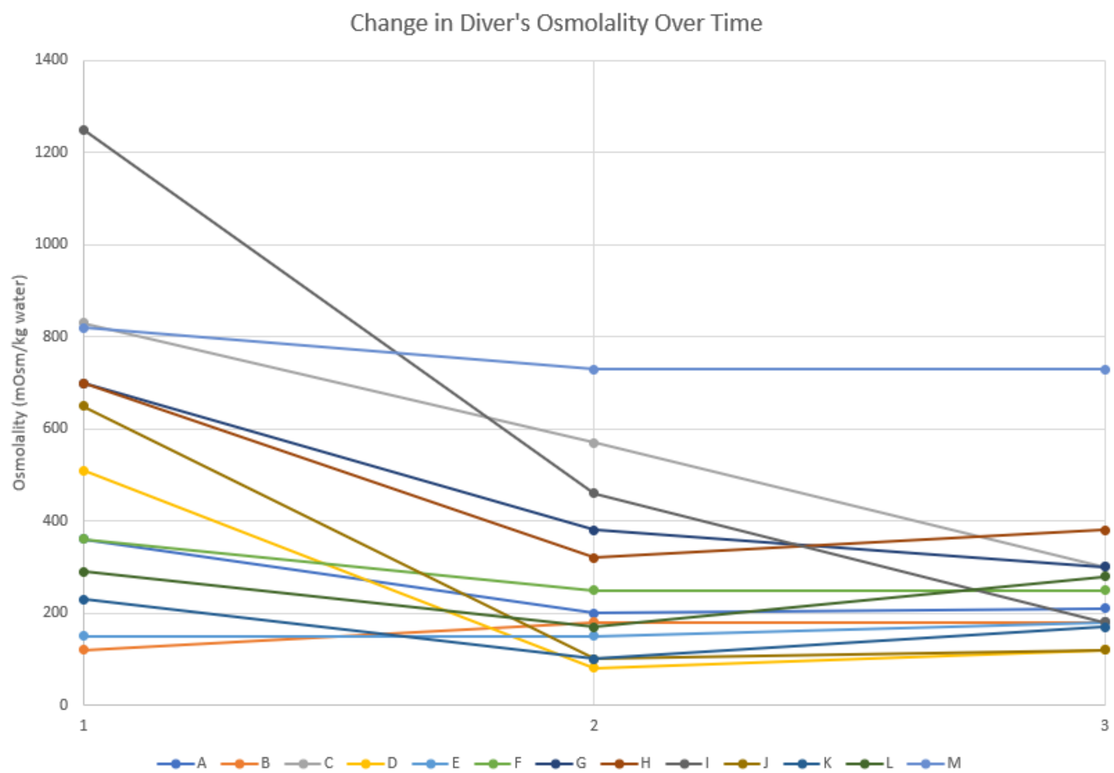


Figure 8: Change in diver's urine osmolality from predive (1), surface interval (2), and post dive (3) measurements.

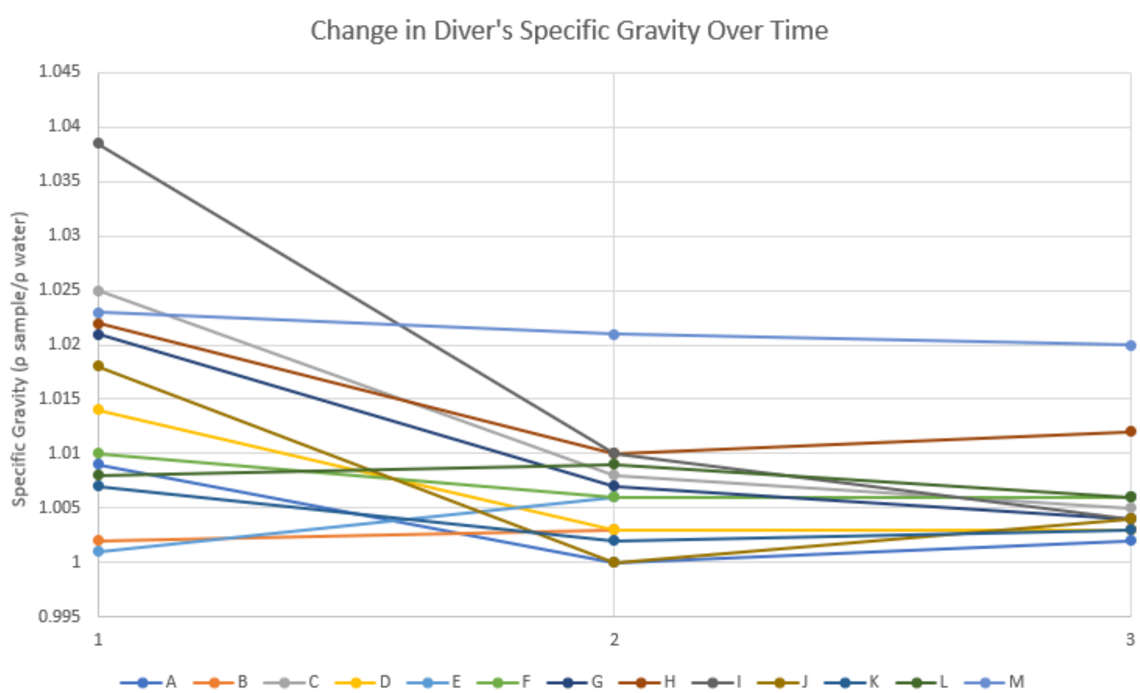
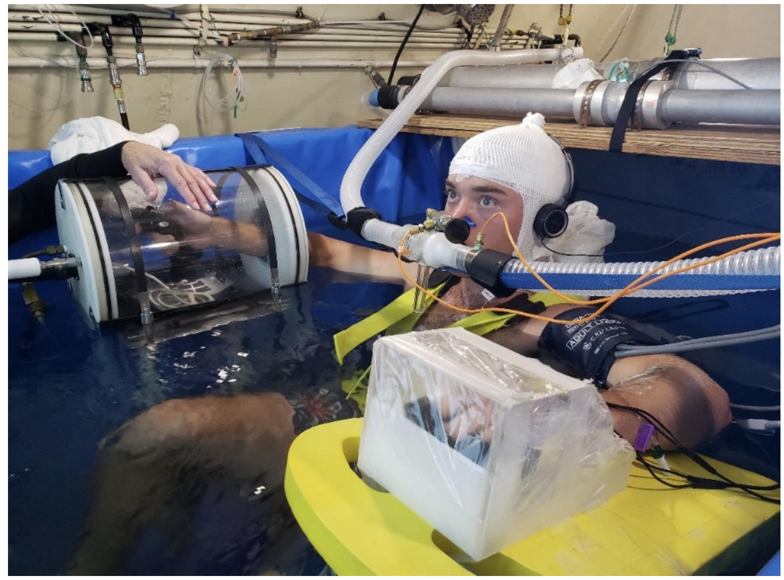
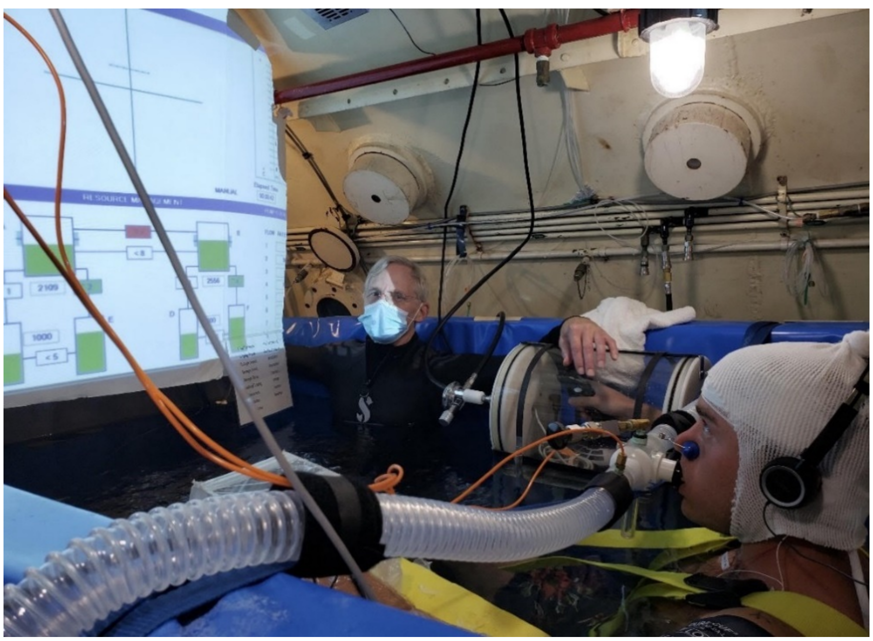


Figure 9: Change in diver's urine specific gravity from predive (1), surface interval (2), and post dive (3) measurements.

Duke Keto/VGE Studies

At Duke's Hyperbaric Chamber, I participated in two research studies over the summer. One of the studies was called "Ketogenic Diet for Reduction of CNS Oxygen Toxicity in Divers." A ketogenic diet has been shown to reduce the number of seizures in children with epilepsy, so it is hypothesized that this diet could be preventative against a similar condition of oxygen toxicity in divers. I went to the chamber three times during this study for an initial screening day, keto diet day, and normal diet day. Three days prior to the keto day I started a keto diet which consisted of eating lots of fat and protein and minimal carbs. The goal of the diet is to reroute the body's fuel source from carbohydrates to ketones. I was placed in a pool with water up to my shoulders inside one of the chambers and hooked up to an EEG, ECG, IV line, blood pressure cuff, and skin conductivity device. I was breathing 100% oxygen through a tube and the chamber was pressurized to 35 feet of seawater. During the study, I was peddling on an underwater ergometer and playing a video game where I controlled a joystick for flight simulation. The same procedure was used for the normal diet day two weeks later, but I was eating a normal diet leading up to the test day. The goal of this study is to see if the keto diet delays or prevents altogether symptoms of CNS oxygen toxicity from occurring. This study is ongoing, and results have not yet been published. I was able to go 1 hour and 15 minutes before symptom onset on the ketogenic diet, and 55 minutes before symptom onset on the regular diet. Both times I experienced the same symptoms of muscle cramps, labored breathing, tingling, and heavy palpitations which were not a result of the relatively easy work load that I had on the bike.





The second of the two studies was similar to some of the field research we did over the summer with DAN. In this study called "Automated Detection of Venous Gas Emboli in Divers," I was given a Doppler cardiac ultrasound to help develop a system to automate the detection of VGE. This is similar to what is being done on decobubbles.com, where anyone can sign up to become a bubble counter to develop automated VGE detection and counting.

Courses

I was able to continue my diving education during my time at DAN through many courses. We took Diving First Aid Pro, Nitrox, Rescue Diver, Self-Reliant Diver, PSI/PCI Cylinder and Valve Inspection, Dive Rite Regulator Repair, and Human Factors in Diving. I learned many skills through these courses and have been applying them during my dives to make me a safer diver for myself and others.

Conclusion

Science and SCUBA diving make a great combination. I have learned so much about dive physiology, physics, and chemistry this summer and there is still so much to learn. I hope to continue my education on dive medicine in the future by taking the courses provided to physicians to become competent in the field. I hope to stay on the DAN research team in the near future to work on continuing and new projects. I have made some great friends during my time here at DAN, and memories that I will cherish forever. My professional experience has grown immensely, and I have great connections for possible jobs or mentors in the future. I can not thank DAN and OWUSS enough for providing me this great opportunity!

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Francois Burman (Director, Risk Mitigation)

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Citations

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