DAN’s DCS Database Deep Dive

Regular readers of this magazine will be aware that personalized decompression is a primary long-term research goal pursued by DAN Europe’s science team under the leadership of Prof. Alessandro Marroni.

This is no easy mission. Studies in hyperbaric science typically have very small sample sizes, which makes it exceedingly difficult to isolate individual factors with statistical significance.

DAN, however, has an ace up its sleeve – or a whole deck of cards, as the case may be: a database of 127,957 real-life dives, including 628 that have resulted in DCS, complete with data from dive computers, collected over a period of 15 years. Accumulating such a vast amount of data, and harmonizing records from different brands of dive computer so that they can be compared, represents a monumental effort on part of the researchers.



The records were contributed by 5,907 individual divers, about 80% of whom were male, 20% female. Each participant submitted between 1 and 1,432 dive profiles (median: 3).

Every single one of these profiles comes with additional documentation in the form of a questionnaire filled out by the diver, in which they provide basic personal data like age, sex, height, weight, as well as information about their physical well-being and how they experienced the dive.

In a recently published study, DAN researchers ran a complex statistical analysis over their entire database in order to identify parameters that influence the probability of a dive resulting in a DCS hit. To this end, dives were bucketed into two main groups; those that resulted in DCS and those that didn’t. The scientists then compared both groups for a range of potential metrics that may influence the likelihood of a

dive ending up in either group.

Let’s take a look at the findings.

Dive profile

Dive profiles were analyzed to identify the *leading compartment* – i.e. which one of the 16 theoretical tissue compartments in the Bühlmann ZHL-16C algorithm had the highest supersaturation – as well as the *gradient factor* for that compartment upon surfacing, i.e. the gas tension relative to the theoretical maximum (M-value), expressed as a percentage.

Since not all dive computers natively use the Bühlmann algorithm or track the gradient factor upon surfacing, the scientists had to retroactively calculate necessary values from the dive profile information. The resulting metric (called *DAN Surface Supersaturation Gradient,* or *DSSG*), was used as the basis for comparison.

Dives resulting in DCS were found to have a significantly higher DSSG than dives that ended without incident (86.6% vs. 74.3%). DCS risk was also found to be greater when the leading compartment had a shorter time constant (colloquially known as ‘fast tissue’). Divers can control both of these risk factors by making extended stops in shallow water before surfacing.

Overall, the dive profile was found to be the single most important factor determining DCS risk.

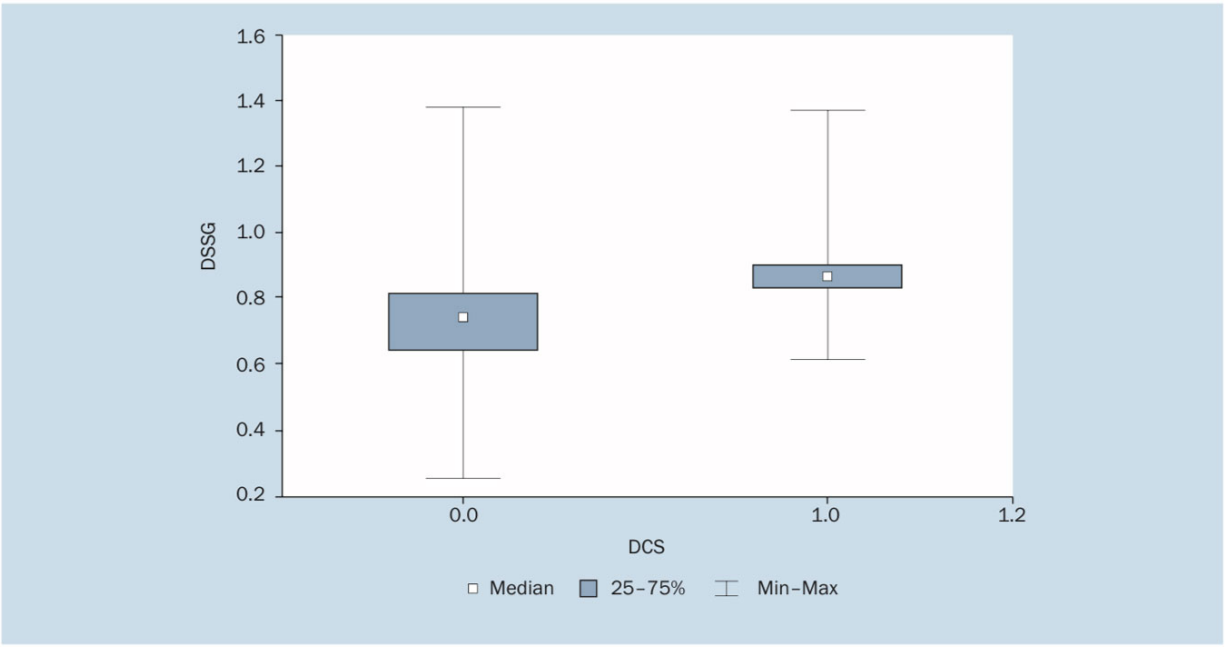


Figure 4. Probability of decompression sickness (DCS) as depending on DAN Surface Supersaturation Gradient (DSSG) in univariate analysis

DSSG for dives resulting in DCS (right) vs. not resulting in DCS (left). The dark box shows the middle two quartiles (half the number of dive profiles). The bars show the extremes of the range.

Being female

On average, female divers appear to have a greater risk (about four times higher) of suffering DCS than

males.

The cause for this discrepancy is not entirely clear. It may be related to factors like sex differences in endothelial function (cell membranes), blood coagulation, and the inflammatory response to decompression stress. Laboratory studies have shown that the factors determining resistance to DCS are not the same for males and females – in rats. This may well apply to humans, too.

In an email conversation with *Alert Diver*, the researchers stated that the current DAN study does not differentiate between female divers of pre-menstrual, fertile, and (post-)menopausal age, and that this differentiation might provide further clues as to the exact mechanisms at work in the future.

For context, it is worth bearing in mind that serious DCS remains exceedingly rare for people of either sex. If you multiply a very low number by four, you still have a very low number. So please keep diving and don't hang up your fins!



Tech diving

Technical diving is riskier than recreational diving. All else being equal, dives identified as 'technical' carry a 36% higher risk of DCS than recreational dives.

In the study, the number of gases carried was used as a stand-in for the magnitude and complexity of a tech dive, and the DCS risk was found to correlate with that number. The researchers concede that with the increasingly common use of CCRs, the number of gases carried becomes less useful as a metric.

Body Mass Index (BMI)

The DAN researchers grouped divers into eight BMI categories, from severly underweight to morbidly obese. The BMI category (not BMI directly) was found to correlate with DCS risk, and – this is one of more surprising findings of this study – not only for overweight or obese divers.

Instead, the curve is U-shaped, with increased risk at both ends of the spectrum. That is, being severely underweight appears to increase a diver's risk of suffering DCS (+15%). Statistical significance was shown only for the extremes – pathologically lean and pathologically obese people.

Repetitive dives and surface intervals

Interestingly, repetitive dives were found to carry a lower DCS risk than preceding ones, lending further support to the concept that the human body adapts to decompression stress. The researchers write that all dives with a surface interval of 48 hours or less were regarded as repetitive.

In conjunction with the finding that each additional hour of surface interval reduced DCS risk by 6%, this suggests that doing a low number of dives per day, with long surface intervals and over several consecutive days, might be the safest approach in terms of managing DCS risk.



Fatigue, exercise before diving, workload during a dive, and thermal comfort

In the questionnaire, divers were asked to provide information on whether they had exercised before a

dive (four categories from no to heavy exercise), if they felt cold or fatigued, and how they rated the workload during the dive.

Exercise pre-dive yielded a positive correlation with DCS risk. The researchers write that this finding should be treated with a high degree of caution, since exercise is a complex topic and not easily captured in a single parameter. In addition, dedicated studies suggest that pre-conditioning with light exercise before a dive can be used to reduce DCS risk.

Both feeling fatigued and feeling cold were found to be protective (reducing DCS risk). These results may appear counterintuitive. With cold in particular, a well-known 2007 study by the US Navy Experimental Diving Unit (NEDU) showed that being cold during the bottom phase and warm during ascent reduces DCS risk. A possible explanation is that noticeable discomfort (self-reported) may cause a diver to act more conservatively.

High workload (again self-reported) was found to increase DCS risk, which is consistent with established knowledge.

Future research

It is in the nature of this study that parameters like fatigue, pre-dive exercise, workload, and thermal status cannot be measured objectively, which makes the findings in these areas less conclusive than those on dive profiles or sex differences, for example.

Getting to the bottom of these important interdependencies requires the use of biomonitoring devices that capture factors like heart rate, breathing rate, blood oxygenation, skin and core temperature. DAN has been actively pursuing research in this field for many years with its in-house DANA Health system and is planning to expand its efforts using a new wearable underwater biomonitoring device capable of delivering a full ECG underwater (*Alert Diver* reported).



Words from the researchers, and an outlook to the future

Asked to sum up the study's results, Prof. Costantino Balestra emphasizes that many of the findings are suggestive, not definitive:

> *"The paper delivers a number of hints that there are two different types of parameters, some dependent and others independent of the DCS risk, and that they do not always line up with conventional wisdom. For instance, BMI was related to an increased risk only at the extremes of 'very lean' or 'very fat.' The parameter with the most predictive power identified in the paper was DSSG."*

DAN EU founder and CEO Prof. Alessandro Marroni provides an outlook to the future:

> *"This study is a first, important step toward the personalization of diving risk according to individual characteristics, level of risk appetite (high, medium, low), diving modalities, type of equipment, and gas count.*
>
> *Combining these findings with the growing volume of data on physiological responses to diving will allow for the second step toward a true individualization of diving practices: the development of a probabilistic, physiological model to mitigate and control individual risk."*

For us divers, the study does not yet come with clear recommendations on how to plan our decompression or set our computers, beyond being conservative with our gradient factor (high) and ascending slowly from

the final deco or safety stop.

However, future dive computers are likely to include a growing number of biometric functions. Research like the study featured in this article will be needed to interpret the measurements and provide actionable advice.