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post-publication comment on:

Dive Risk Factors, Gas Bubble Formation, and Decompression Illness in Recreational SCUBA Diving: Analysis of DAN Europe DSL Data Base

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This work of european DAN is not only intellectualy stimulating but as well of paramount importance to the further development of safety for recreational divers. It may also help to mitigate the somewhat heated and superfluous debate in the (technical) diving community as to which decompression model (perfusion, diffusion, dual phase) or which dive computer might be the best.

Nevertheless there are a couple of boundary conditions which will probably evade the non-diving reader from the fpsyg-portal.

1a) The 83 : 17 relation of participants, which yields a ratio of ca. 4,9 of males over females is an imbalance which probably may not reflect properly the european recreational divers population. This might be a first indicator of a biased database.

1b) As well the „mean“ age seems to reflect a somewhat non-standard diver population; the majority of divers being usually younger. As per nearly all human activities, there is a drop-out rate: for ca. one instructor/TEC/advanced diver there are approx. 100 freshman. So here the beginner and intermediate diver population seems to miss.

1a & 1b could be checked against the statistics of the issued diver certifications of the major training agencies like PADI and/or SSI.

2) 320 cases of DCS would yield:
- ➔ an average rate of ca. 64 p.a.
- ➔ and an overall rate of 320 / 39.099 of ca. 0,81 % which, both, are substantially more than reported elsewhere (ca. 1: 10.000 in [1], p.544; and as well in [2], p. 151).

Certainly, the divisor is not known and the rates are taken as a surrogate. And, as well, other, more elaborate studies, would reveal, for eg.: **Decompression illness in divers treated in Auckland, New Zealand, 1996-2012.** (Ref.: https://www.ncbi.nlm.nih.gov/pubmed/24687481): that there are 520 DCI cases in 17 years, which would equate to ca. 31 p.a. and thus yield a factor of ca. 2 lower.

Similarly a recent study showed (Ref.: Svendsen Juhl C, Hedetoft M, Bidstrup D, Jansen EC, Hyldegaard O. Decompression illness treated in Denmark 1999–2013. Diving and Hyperbaric Medicine. 2016 June;46(2):87-91.) 205 DCI cases over 15 years; reduced to recreational cases, the rate is ca. 11 p.a. The factor male/female ca. 3.8. This study reveals that ca. 80 % of the DCI victims are up to an intermediate certification level, and ca. 50 % consider themselves as with relatively little experience.

Another example, albeit taken from the military diving community (**DJRS, the Dive Jump Reporting System of USN** (United States Navy); Ref.: http://divingresearch.scripts.mit.edu/militarydivingdata/) which sports with with 4 cases of DCS and 5 of missed decompression out of 768,851 dives, collected from 2008 to 2015.

This might be as well a 2nd. indicator of a biased database.

3) 39,099 dives per 2,629 divers would yield ca. 15 dives per diver. It might be somewhat speculative, but 15 dives out of an average diving carreer do probably not represent an average sample concerning both dive depth an dive time. Thus this could imply that the uploaded samples have been the most recent ones or the most spectacular ones (with a topical tendency from October 2017 of 63.248 from 5.326 divers, giving an average of 12, sinking). Especially when considering that approx. 15 to 20 individuals (including the author), each

donating in the average ca. 500 dives, thus contributing a substantial amount of profiles and thus decreasing the average of the rest. [Remark: input dives from author @ rank 1: 762]

4) Studies with volunteer participants regularly imply often a self-selected group, the sample usually not reflecting the real population. This could imply another, i.e. the 3rd. bias: participants which like to deal with the technical pecularities of transferring log-files from a dive computer to a PC, then converting the stored dive log-files to a DAN compatible format, then uploading these files from the PC to the DAN DSG portal and finally filling in the ca. 20 statements per uploaded dive.

5) The average dive depth / dive time given as mean ± standard deviation, would imply, at least for a somewhat naive reader, sort of normal distributions for these variables, which would be, in my personal experience, relatively unprobable. Otherwise the study fails to reveal the statistical connection between diver B doing a dive in country X to depth z with a buddy-pair C, diving in country Y to depth to 0,5 * z with diver A (the author) contributing in country DE a controlled dive in a decompression chamber to depth 2 * z, the mean being clearly z, but obviously of only limited intellectual value (Ref.: https://www.divetable.info/skripte/50m_deco.pdf. The funny side of things is that these profiles normally earn already a big yellow smiley in the DAN DSG portal, thus warning of a somewhat medium DCS risk).

For eg. the above cited USN study reveals clearly skewness, with a slope (note the log scale!) from shallow to deep and more probably of a certain Poisson type than Gaussian. Thus, a frequency analysis in appropriate classes (depth bins with 5 or 10 m resp. for the dive time) would have given a clearer picture.

6) As well the mean of 27.1 m (range 5–104), where the .1 is clearly a statistical artefact, which could have been dropped happily: dive computers tend to give the first digit not precisely. Anecdotal reports [3], [4] and controlled laboratory experiments [5], [6] indicate this very clearly. Additionaly, a lot of dive computer manufacturers fail to demonstrate a proper temperature drift compensation (and the compensation of other drifts) for their products.

The value of 27 could be as well an indicator of a certain bias: the suspected missing of beginner and intermediate dive-profiles, being in the 6 to 18 m range for beginners and in the 15 to 30 m range for intermediate divers. Even more so, when considering beginner and intermediate divers as relatively neutral to decompression-theories, -calculation and -tables; some of them not even owning a dive computer and thus not being able to collect and upload the dive profiles to DAN.

7) To exclude Trimix makes sense, probably there is another mechanism of bubble arterialisation and other inert gas kinetics due to Helium (for the non-diving reader: Trimix is a breathing gas, consisting in various fractions of the 3 gases Oxygen, Helium and Nitrogen (thus Tri-), whereas simple compressed Air or Nitrox are not.) As well the ZH-L framework from Buehlmann et al. [7], used in this study, has been, up to now, not really challenged with trimix for multi-level diving. (And b.t.w. this algorithm is diverging around a compartment half-time of 1,005 min, which, used unmodified, would render it useless for the, from DAN intended, analysis of breathhold diving).

8) Dives, for eg. to 104 m depth on air, will yield profiles of an extreme spike form which are probably not in line with common diver behaviour, be it recreational, military or commercial: the limitation of breathing gas supply makes bottom times very short, especially when dived with a single tank; which the study tacitly implies. If done otherwise, the study should reveal it.

9) Also, for the non-diving reader: a dive on Air in the 3-digit range is subjected to inert gas narcosis, which is likely to start beyond 40 m and oxygen toxicity, beyond 80 m, which makes these profiles, operationally wise, not only relatively dangerous, but, to put it mildly, somewhat „experimental“: the ascent and descent rates are not in line with standard procedures. Thus one could question the statistical wisdom of not excluding these experimental dives.

10) In conclusion, the study leaves open a couple of questions respectively room for improvement:

- ➔ Diver biometrics and dive circumstances are entered through the divers themselves. How is the quality of these inputs assessed?
- ➔ Screening for PFO or other individual susceptibilities?
- ➔ Blinding of operators, recieving the doppler signals? Control group?
- ➔ Table 3 reveals a conundrum of multi-collinearity: how is this adressed?

11) Nobody should be caught by surprise, that the mapping of a deterministic perfusion model (ZH-L) to a stochastic phenomenon (DCS) is of only limited success. Thus the relative failure of printed decompression tables or dive computers. Once again, as per remark # 7, the ZH-L (or, basically all perfusion models) was never really challenged with extended multi-level or reversed dive profiles, common in recreational diving. The described modifications ([7], p. 157, 196) to allow for real-time calculation being marginal: the clear message is that the M-

values (or, in ZH-L parlance, the a- & b coefficients) derived from box-profiles, and, maybe, the spectrum of compartment half-times need repair.

This even more so, when considering that dive computers are „black boxes“ for the diver: leaving the user completely in the dark, how a decompression algorithm is implemented and which constants are used. Thus it is also of no surprise that for a given box-profile the calculated stop times for the decompression stops differ easily with a factor of 4 to 8; even if the manufacturers in question claim to have implemented a „real ZH-L“ (Ref.: https://www.divetable.info/skripte/HBO-RMT.pdf and [10]).

One of the really important findings is, that the dives seem to be basically in the „safe zone“: thus nobody should be caught by surprise, that the group of „medium“ compartments is involved. The mentioned slower ascent rate, although not specified in the study, and „deep“ or deeper and longer stops, give the fast compartments time to de-saturate while the medium and slow ones still saturate. For real world recreational diving, the take home message seems to be:

„If you go slow, go even slower!“ (especially in the shallow 9 to 6 m zone).

12) Now, finally in taking points # 1) to 4) as a basis, chances are that there could be a bias of the actual database; one of the confounding factors being diver experience and another one the liking of handling purely technical problems. My private speculation and personal experience is, that this relatively special group of highly trained and motivated (mediterranean) divers, which dedicates a lot of their spare time for the DAN DSG portal tends to dive in a way that is, in some way or another, disjunct with the population of recreational divers, thus prone to a higher rate of DCS.

I would not go so far as with Altman, who states: „Misuse of statistics is unethical, as well it is shoddy science.“ [8]; but clearly a couple of tenthousand non-DCS dives with moderate time/depth profiles have to be added. As well a functional peer-review process, in-line with established statistical thinking would be a benefit.

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