## Letter to the Editor

# A deep stop during decompression from 82 fsw (25m) significantly reduces bubbles and fast tissue gas tensions.

### Response by the Authors

We thank Risberg and Brubakk for their comments. While we do not agree with them, we welcome the opportunity for clarification. Their criticism falls into the following categories:

1) Calculation and references to supersaturation in particular "tissues" and relating it to Doppler scores.

Decompression theory based on "tissue" saturations is a working hypothesis. It has been continuously modified in an effort to avoid clinical decompression sickness – with varying success — for more than 100 years. Unlike dive tables, however, dive computers allow great latitude in ascent rates within a maximum limit. Our study therefore endeavoured to demonstrate that all "safe" ascents are not biologically equal – the empirical introduction of the safety stop being an intuitive response to this knowledge.

For this observational study we compared mathematically predicted ”tissue” saturation to a biological marker – Doppler. We chose the Buhlman model for convenience and because it is in common use. We neither assumed the predicted ”tissue” saturations were correct nor that they had any particular meaning. Like Newton, we did not tell the ”apple” how to fall, but merely observed how it did.

2) The impact of ascent time vs. precordial Doppler scores.

The data presented in our paper are all consistent with the observation that total ascent time does not correlate with precordial bubble scores and that stops are more determinant than the ascent time or rate. Where and how you spend your ascent time appears more important than how much time you spend.

3) The methodology regarding Doppler measurement and interpretation:

The manuscript states: …the recordings were later analyzed by a blinded, experienced researcher…". The Doppler technicians were only instructed in how to ensure a good quality recording – not how to interpret it. Recordings were submitted for analysis without the associated dive profile information. All evaluations were performed by the same researcher (with extensive experience in Doppler assessment), so inter-rater variability (Cohen's Kappa) does not apply.

4) The Doppler Scoring System:

The authors' elected to show conclusively that the type of scoring system did not effect the result: dives without deep stops had statistically higher bubble scores than those without – irrespective of the scoring system.

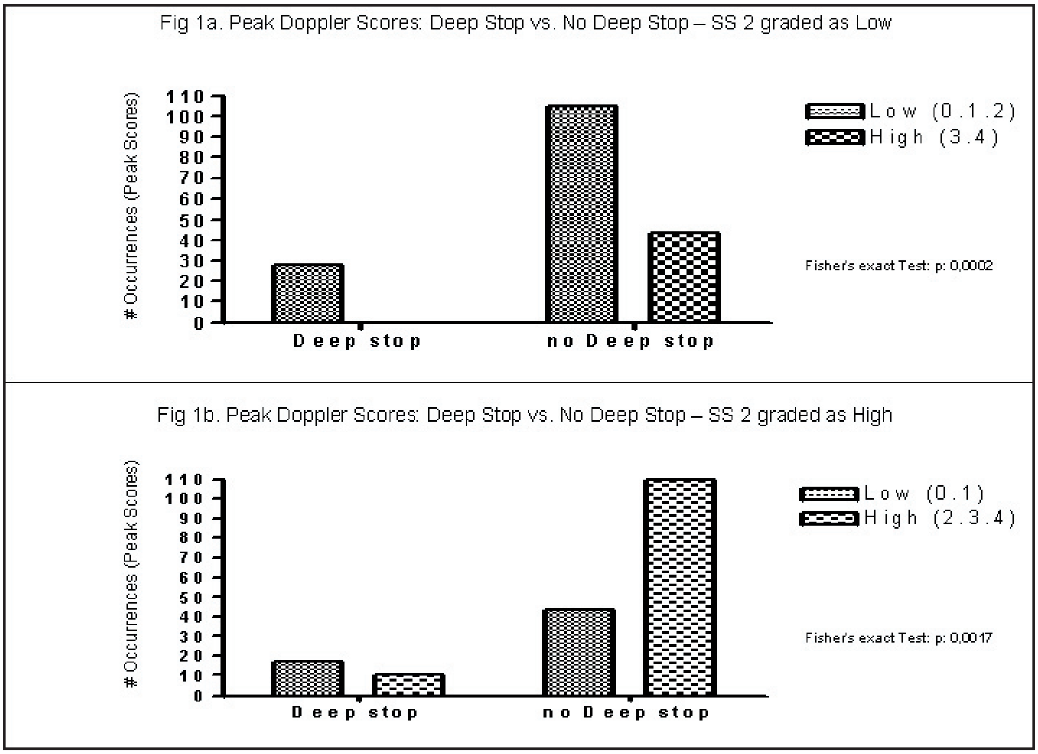

Fig 1a. Peak Doppler Scores: Deep Stop vs. No Deep Stop – SS 2 graded as Low

Fig 1b. Peak Doppler Scores: Deep Stop vs. No Deep Stop – SS 2 graded as High

5) The statistics:

We covered many possibilities with the original pre-publication reviewers. They had access to the raw data and several tables and data presentations were based on their recommendations. Importantly, however, when comparing the Doppler scores by any scale, the differences between dives with deep stops and those without remained significant. Therefore irrespective of any criticism on the scoring system used, or the statistical validity of the BSI, the Doppler bubble indices were statistically reduced by a deep stop and this was irrespective of the total ascent time.

As to the actual analysis: this was performed assuming that the Doppler scores could be compared to "class ranking of students or APGAR test results in newborns..." (Motulsky)[1]. We chose non parametric analysis of variance to test our data in repeated measures (Friedman test) and non repeated measures with multiple comparison post tests (Kruskal-Wallis with Dunn's test). Although the reviewers accepted this, we recognise that others might not. Accordingly, in response to Risberg's comments, we performed a comparison between the proportion of peak Doppler measurements using Fisher's exact test to analyze the effect of deep stops on high peak bubble grades which – as stated by Risberg – are associated with biological injury. The results again support our original findings. To accommodate further differences of opinion, we respectively analysed the peak Doppler data using SS Grade 2 as low bubble grade in Fig 1a. and as high bubble grade Fig 1b.

6) Doppler scores vs. DCS:

The authors did not wish to extrapolate beyond the data nor attribute a clinical diagnosis to the physical phenomenon of Doppler signals. The primary rhetorical comments were these:

On Predicted Tissue Saturation:

(1) spinal DCS is prevalent in deep recreational air scuba diving; (2) Buhlman – based on his research – attributed spinal DCS to supersaturation in the 12.5 minute "tissue"; (3) for this particular dive the (mathematically predicted) leading "tissues" had 10 to 20 minute half times; (4) the dives with ascent profiles without deep stops had higher saturations of the 10 and 20 minute "tissues". Interestingly, Doppler scores appeared to correlate with higher predicted saturations in these "tissues". The authors therefore proposed this may be deserving of more attention.

Regarding Doppler:

(1) For diving research within the limits of low probability for clinical DCS, Doppler scores – although imperfect – provide the only relative measure of decompression stress; (2) high Doppler scores or "many bubbles", while not synonymous with DCS, are not innocuous; a fact also supported by Risberg and Brubakk respectively (2,3).

In closing, the "take home" message of our paper is the observational finding that all "safe ascents" from an 82 feet (25 MSW) dive are not biologically equal. For this particular dive profile there was a full range of precordial bubble scores: the bubbles were highest following linear ascents and lowest when two stops were performed. Total ascent time did not determine Doppler scores so that the conclusion must be that the deep stop does.

A number of diving organizations have already introduced a deep stop on a completely empirical basis. Our study offers the first evidence in support of it.

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