Observed decompression sickness and venous bubbles following 18-msw dive profiles using RN Table 11

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ABSTRACT

The venous bubble load in the body after diving may be used to infer risk of decompression sickness (DCS). Retrospective analysis of post-dive bubbling and DCS was made on seven studies. Each of these investigated interventions, using an 18 meters of sea water (msw) air dive profile from Royal Navy Table 11 (Mod Air Table), equivalent to the Norwegian Air tables.

A recent neurological DCS case suggested this table was not safe as thought. Two-hundred and twenty (220) man-dives were completed on this profile. Bubble measurements were made following 219 man-dives, using Doppler or 2D ultrasound measurements made on the Kisman-Masurel and Eftedal-Brubakk scales, respectively.

The overall median grade was KM/EB 0.5 and the overall median maximum grade was KM/EB 2. Two cases of transient shoulder discomfort ("niggles") were observed (0.9% (95% CL 0.1% – 3.3%)) and were treated with surface oxygen. One dive, for which no bubble measurements were made, resulted in a neurological DCS treated with hyperbaric oxygen. The DCS risk of this profile is below that predicted by models, and comparison of the cumulative incidence of DCS of these data to the large dataset compiled by DCIEM [1, 2], show that the incidence is lower than might be expected.

INTRODUCTION

Upon decompression from a dive made either in water or in a dry hyperbaric chamber, gas bubbles may form in the blood and tissues of the diver. This occurs as a result of inert gases becoming supersaturated in the tissues upon decompression, then coming out of solution and forming bubbles. It is because of bubble formation and its link to decompression sickness (DCS) that dive profiles are designed either to be short enough that only limited gas supersaturation occurs on direct ascent to the surface ("no-stop" dives) or that decompression stops, allowing time for gas to be transported out of the tissues, are built into longer dives (decompression dives) on return from depth to surface.

The amount of ultrasonically detectable intravascular bubbles, or "bubble load," in the body upon decompression is related to the risk or incidence of DCS; however, this relationship is non-linear and is dependent on a number of factors. For example, on examination of data obtained following a large number of air and heliox dives (N = 3,499 subjects) [2] where bubbles were measured with Doppler ultrasound equipment and graded on the Kisman-Masurel (KM) [3] scale, it was found that if no bubbles are detectable after a dive, it is unlikely that DCS will occur. The incidence of DCS associated with the lowest amount of measurable bubbles (KM I) conferred a risk of around 1%, while the highest bubble loads (KM IV- and IV) were associated with a DCS risk

KEYWORDS: decompression; stops; supersaturation; Doppler; ultrasound; bubble data

of around 10%. This large data set has proven to be the "gold standard" to show a correlation between differing venous gas emboli (VGE) grades and DCS. However, other studies with more provocative dives have shown KM IV scores associated with higher incidence of DCS, but that – in part at least – is likely due to a ceiling effect; i.e., the fact that there is no higher bubble grade than IV in the KM grading system [4].

It is because of this relationship between VGE and DCS that post-decompression bubble monitoring is now often used to test the risk of DCS post dive. Doolette, et al. [5] noted that although the relationship between VGE and DCS is not strong, the fact that VGE evolve regularly after diving means that bubbles are potentially more information-rich than low incidence DCS. However, their poor specificity means that VGE grades have a poor predictive value for DCS [5].

Despite this limitation VGE are still used often as a marker of decompression stress, as it is not always ideal (or indeed ethical) to use DCS as a study endpoint – for example, the number of dives that are needed to define a percentage risk for a specific dive profile number in the hundreds, which is both impractical and prohibitively expensive in terms of time and money for most research centres. With the more information-rich bubble detection, the number of dives necessary can be reduced greatly (e.g., Eftedal, et al. [6]), with researchers often using a predetermined bubble grade as a "safe" endpoint rather than the onset of DCS.

In their simplest form, tests using bubble data as indices may be designed to ascertain whether a particular decompression profile is safe. Alternatively, appraisal of prophylactic measures hypothesized to protect against DCS, such as taking a drug, exercising or breathing oxygen before or after a dive, may be made by observing the difference in the number of bubbles produced between control and test dives.

If testing the efficacy of experimental preventative measures, then it is apparent that to prove a difference between the test condition and control, some VGE will need to be observed. If a dive profile is not provocative enough, then a diver might not produce bubbles after both the control and test dives, telling us nothing about the intervention. However, if the diver has a bubble load after the control dive, then researchers have something to measure against. Therefore, a dive profile that is known to produce some bubbles post-dive is preferred when testing prophylactic measures. The ideal profile should be known to be "safe" through experience of diving it many times, and will be known to be bubble-producing in most subjects.

The present retrospective study reports the results from many dives made over seven studies in such circumstances; the profile chosen (a dive to 18 meters of sea water (msw) for 100 minute from UK Royal Navy Table 11 (Mod Air Table) / Norwegian air dive tables [7, 8]) was known to be bubble-provoking, but is in active professional use and so deemed to be safe. The specific data and outcomes for each study are reported elsewhere / are in preparation for publication (see Methodology). However, during the last study (a multiday dive study carried out in Norway) one case of neurological DCS occurred [9]. This raised concern that the dive profile – and hence the entire dive table – was not as conservative, or indeed as safe as thought.

With that in mind, the bubble data from all seven studies were combined and examined with the intent to investigate the hypothesis that this particular profile was producing larger bubble loads than might be acceptable and should be revisited. However, perhaps most importantly, this large compilation of data provides information on the bubble grades for a particular profile dived so many times that it can provide a credible estimate for its probability of DCS.

METHODOLOGY

Data from seven human dive trials were included in this study. All work was carried out in accordance with the Declaration of Helsinki. All participants were given detailed written and verbal information about their respective study, and thoroughly informed of potential risks associated with their participation. The trials were carried out in Slovenia, Sweden, Norway and the United Kingdom and were subject to the respective ethical approval of the appropriate research bodies therein. The seven trials included in this study are detailed in Table 1. The total number of dives evaluated in this study was 220, with bubble measurements made after 219 dives.

Dive profile

The 18-msw dive profile was taken from Royal Navy Table 11 (Mod) (same as the Norwegian air dive tables), and was conducted as follows:

Table 1. The seven human trials included in the present study

study	location	type	dives (N)	subjects (N)	sex	mean age (years)	mean body weight (kg)
1	Sweden	NO intervention	18	9	male	34.1 (+ 6.0)	82.8 (+ 11.5)
2	Slovenia	bed rest	50	10	male	23.0 (+ 2.0)	75.0 (+ 10.0)
3	Slovenia	dehydration intervention	15	10	male	N/A	73.9 (+9.8)
4	Slovenia	dehydration /rehydration	24	10	male	N/A	N/A
5*	UK	cycling exercise	30	10	male	40.6 (+9.5)	BMI 27.7 (+3.7)
6*	UK	pre-dive exercise mode	45	15	male	36.5 (+8.5)	81.2 (+7.3)
7	Norway	inter- and intravariation bubble load	38	10	2 female 8 male	33 (+8.7)	76.5 (+13)

Describing the seven human trials that were included in the present study. N/A denotes that these data were 'not available'; + denotes standard deviation; studies 5* and 6* are published, [16, 17].

Descent to 18 msw at a rate of 15 meters / minute, remain at depth for 100 minutes. Ascent (all at 15 meters / minute, apart from Study 7, where the rate was 9 meters / minute) to first stop at 6 m for 5 min, ascent to second stop at 3 meters for 15 minutes, then back to surface. Total dive time 122 minutes. All dives were made in dry hyperbaric chambers on air and the subjects were told to rest, either sitting or lying in the chamber during the exposure.

Bubble measurements

All measurements were made by the same experienced ultrasound operator, apart from Studies 5 and 6, where additional operators, from the center where the primary operator was trained, also made measurements. All measurements were made using precordial Doppler audio ultrasound and graded on the KM scale (ranging from 0 – IV), bar Study 7; here 2D ultrasound imaging (echocardiogram) was used and bubble loads graded on the Eftedal-Brubakk scale (EB; ranging from 0 - 5) [10]. It has been shown that the KM and EB grading systems correlate well with one another [11] and the relationship between the two grading systems is shown in Table 2.

In order to make the measurements, in all studies apart from 5 and 6, the subjects were asked to lie down in the left lateral decubitus position and the operator then placed the ultrasound probe on the skin over the heart to grade any bubbles that were audible / visible. In Studies 5 and 6, the subjects remained on their feet, upright, while the probe was placed on their chest and the operator listened to their heart.

Table 2. Overall frequency of maximum bubble grades

KM grades	rest	flex	rest % (Sawatzky data)	flex % (Sawatzky data)
0	75	26	34 (73)	22 (67)
I	28	8	12 (8)	7 (6)
II	44	17	20 (8)	15 (6)
III	72	54	33 (11)	46 (18)
IV	1 (IV-)	12	0 (0.2)	10 (2)
N	219	117	(219 vs 1726)	(117 vs 1726)
median grade	II	III		

Overall frequency of maximum bubble grades observed post dive, both at rest and flex (where data were recorded). Also included for reference is the corresponding percentage occurrence of each grade as reported in the Sawatzky data [1].

Bubble measurements began at five minutes post dive and were made every five minutes for the first 30 minutes, then every 15 minutes thereafter up to two hours post dive. Resting measurements were made as standard; some measurements were also made after movement (flex; flexing both legs three times while remaining supine, or performing a deep knee bend when standing upright), though not in Studies 2 (where movement was not permitted for the bed rest protocol), 3 and 7 (as the EB scale was not designed to accommodate movement; in the future, as a result of the Ultrasound 2015 consensus debate and recommendations [12], movement is likely to be included as standard when using this grading system).

Most of the bubble data reported include both control and test results. Overall, no demarcation between the two was made, as the aim of the present study was to look at the range of bubble grades and to assess the degree of safety of this dive profile, whether an intervention was being made or not. However, bubble data for the control dives are presented for interest.

Statistics

The resulting bubble grades are ordinal in nature and therefore any statistical manipulation must be made with care, using non-parametric tests. Bubble data were described in several ways. The median grade measured following each subject-dive was calculated, then the median of all subject-dive medians was presented as the "median study" to represent that study. Median study was reported for the resting condition only. The median of the maximum grade measured after each subject-dive ("median maximum") was reported for rest and flex conditions. The KM grading system should correctly be reported in the form of Roman numerals (for example II+, III-). However, the KM scores are often reported in Arabic numerals, particularly in tables and figures for clarity and convenience; in these cases, a '+' or '-' is denoted by +/- 0.33, so for example III+ would be represented by a nominal value of 3.33 and II-, by 1.66. The percentage of DCS incidence and the exact confidence limits (95%) were calculated.

RESULTS

DCS

Across the 219 measured dives, no definitive cases of DCS were observed. Two subjects reported "niggles," one in Study 3 and one in Study 4. Both incidents presented as shoulder discomfort that resolved without hyperbaric treatment. The subject in Study 3 presented with slight shoulder discomfort that resolved after 100 minutes with surface oxygen. His resting median KM bubble grade was III+, as was his maximum. On movement, his median KM grade was III+ and his maximum was KM IV. These data were collected following the control exposure, but it should be noted that the subject was very excited after the dive and was jumping around despite requests to desist. The subject in Study 4 presented with shoulder discomfort at 75 minutes post-dive and was given surface oxygen. The discomfort resolved quickly, but then the subject experienced a similar feeling in the other shoulder; that soon resolved as well. He had a resting median bubble grade KM III and maximum grade KM III+, while on movement his median was KM III+ and maximum was a KM IV. These data were collected after an intervention (dehydration) dive, not control.

One of the divers in Study 7 did have a DCS incident. This subject had completed his first dive, then missed his second due to an automobile accident. The decision was made for him to continue with dive three, so that further data for the blood/genome side the of the study could be obtained. However, there was no use for any subsequent bubble data from this subject, so none were measured. Therefore, the results from his first dive only were included in the 219 dive dataset reported here. The subject had then gone home following dive three, spent the evening shoveling snow and had become cold at his extremities before going to bed. Upon experiencing bilateral ankle pain the following morning, some 24 hours after surfacing, he was transported to the treatment facility. At 32 hours post-dive, just prior to recompression treatment, his symptoms had evolved to include additional pain in the left knee and elbow, with slight left-sided paresis in the ankle, elbow, hip and knee. Initial treatment using U.S. Navy Table 6 brought partial improvement. After three additional treatments (100% O_2 for 90 minutes daily at 2.4 ATA (242 kPa)) the diver was symptom-free. It should be noted that the subject missed dive two, as he was in a car crash in which his vehicle was written off as a loss. Although he had declared that he had no physical problems or any pain following the crash (see Møllerløkken, et al. for case study [9]), it is very possible that the car accident factored toward the symptoms observed. This symptomatic dive was counted as the 220th in this dataset.

Overall, the calculated incidence of DCS (N = 1) from these 220 dives was 0.45% (95% CL 0.1% – 2.5%). If the two dives causing the shoulder niggles are considered as incidents, then the incidence for these two alone is 0.91% (95% CL 0.2% – 3.3%), while the total incidence (N = 3) of DCS was 1.36% (95% CL 0.5% – 3.9%).

Table 3. Frequency table for both maximum resting and flex measurements

BG rest (KM)	Study 1	Study 2	Study 3	Study 4	Study 5	Study 6	Study 7 (EB)
0	3	8	7	4	2	2	2
I	0	0	0	1	1	3	2
II	1	0	0	1	3	5	3
III	5	2	1	1	4	5	3
IV	0	0	0	0	0	0	0
n	9	10	8	7	10	15	10
median (max rest)	III	0	0	0	II	II	2
BG flex							
0	2	no data	no data	5	2	3	no data
I				0	1	1	
II	2			0	0	5	
III	3			2	7	5	
IV	1			0	0	1	
n	9			7	10	15	
median (max flex)	II			0	III	II	

Frequency table for both maximum resting and flex measurements (no flex data for studies 2, 3 and 7) from the CONTROL dives alone. All data are KM Bubble grades, bar those in Study 7 that report 2D ultrasound data graded on the EB scale. BG - Bubble grade.

Bubble measurements

To give the reader a sense of the effect of the interventions in these results, Table 3 details frequency bubble data for the control dives alone.

From 219 dry chamber dives made on this 18-msw profile, maximum resting bubble grades ranging from 0 to KM grade IV- and EB 3 were observed, and from KM 0 to IV upon flex (movement); Table 4 describes the overall frequency of the maximum bubble grade for each dive at both rest and flex where measured. The frequency data for each Study are also detailed in Table 4 and the median of the maximum rest (median max rest) and flex (median max flex) grades are also shown.

Where KM and EB grades are reported in combination (e.g., Table 4), the grades are denoted in Arabic numerals. The median grade (KM or EB) for each study (median study) was also calculated as described in the statistics section of the methodology and displayed in Table 5. The median study grade ranged from 0 – 1.25, with the overall median of these values being 0.5 (N = 219). The median maximum grade for each study ranged from 0 – 3 (KM III), while the median (all studies) for the overall maximum grade was 2. Table 6 describes the percentage frequency of each bubble grade against the incidence of DCS, and compares it to the DCIEM data [1] for both rest and movement.

DISCUSSION

The data reported in the present study provide a large compilation describing the relationship between different VGE grades and DCS cumulative incidence for one particular dive profile. They offer the only such single-profile dataset that we are aware of for VGE detected with Doppler / 2D ultrasound and graded on the KM / EB scales.

Bubble measurements

Median study grades are often used to give an overall idea of the bubble load provoked by a dive profile, while maximum grades and particularly the frequency of their occurrence, are often used to infer the

Table 4. Bubble data table for overall values and individual studies

BG rest (KM)	**Study 1**	**Study 2**	**Study 3**	**Study 4**	**Study 5**	**Study 6**	**Study 7 (EB)**	**Overall rest**
0	7	30	10	11	3	7	7	75
I	1	7	1	2	2	8	7	28
II	2	7	3	4	9	12	7	44
III, III+	8 (7)	6 (2)	1(1)	7 (2)	16 (6)	17 (10)	16	71
IV, IV-	0	0	0	0	0	0 (1)	0	(1)
n	18	50	15	24	30	45	37	219
median (max rest)	II	0	0	I	III	II	2	II
BG flex								
0	4	no data	no data	11	3	8	no data	26
I	2			0	2	4		8
II	2			3	0	12		17
III, III+	7 (6)			9 (1)	23 (9)	15 (7)		54
IV, IV-	3			1	2	6		12
n	18			24	30	45		117
median (max flex)	III			II	III	II		III

Bubble data frequency table for overall values and individual studies. Detailing both maximum resting and flex measurements (no flex data for studies 2, 3 and 7) from all dives (control and intervention). All data are KM bubble grades, bar those in Study 7, which reports 2D ultrasound data graded on the EB scale.
BG - Bubble grade. Number of KM III+ and IV- are given in parentheses.

upper level of risk of a profile. For example, they may help to determine if a new table will be accepted or rejected in terms of safety cutoff limits.

Varying professional bodies accept different levels of risk; for example, in the early days of dive table validation by DCIEM for the Canadian Navy, a profile was considered stressful if it produced maximum bubble grades greater than KM II in more than 50% of the subjects [13]. That was later amended, with the new criterion for acceptability being a profile where less than 50% of subjects have bubble grades with KM III and IV [1]. A recent collaboration between the Swedish and Danish Navies to derive new trimix tables have set their level at the median of the maximum being less than or equal to KM III. Using either the amended DCIEM or the Swedish and Danish criteria, then the table detailed in the present study, with an overall median maximum Grade 2, would be within acceptable limits. Note that all of these cutoff values refer to maximum grades at rest.

If data from the present study are examined against the large dataset reported by the Canadians in 1991 [1, 2], then we can see that it appears that there is some consistency between the two, as the niggles from the present study and the Canadians' higher incidence of DCS occur with the higher bubble grades (Grade III and above) (Table 6). We can also compare directly our data of 219 dives on a single profile with a subset of the large DCIEM dataset (1,726 dives), detailing the correspondence between DCS and maximum bubble grades obtained following dives measured with precordial Doppler alone. Table 6 describes the percentage frequency of each maximum bubble grade against the incidence of DCS, and compares it to the DCIEM data, for both rest and movement (flex). As the frequency of higher grades is much greater for the present study (for example, 32.9% KM Grade III at rest as opposed to only 11.1% in the DCIEM data), it might be expected that the incidence of DCS would be greater. However,

Table 5. Resting bubble data and DCS occurrence for each of the seven studies

US mode	Doppler	Doppler	Doppler	Doppler	Doppler	Doppler	Echo
study	1	2	3	4	5	6	7
n	18	50	15	24	30	45	37
median study	0.5	0	0	0	1.25	1	0.5
med max (rest)	2	0	0	1	3	2	2
range (median max rest)	0–3.33	0–3.33	0–3.33	0–3.33	0–3.33	0–3.66	0–3
DCS*	no	no	1 niggle	1 niggle	no	no	no

Resting bubble data and DCS occurrence for each of the seven studies. US=Ultrasound. (Please note, Arabic numerals used for convenience; there are no denoted bubble grade equivalents for medians such as 0.5 and 1.25).
*DCS occurred but is not included in this summary, as no bubble measurements were made.

Table 6. Comparison of rest and flex bubble grade data and DCS incidence against pre-cordial, air dive data [1, 2]

	Precordial at REST	**N**					
	bubble grade		**0**	**I**	**II**	**III**	**IV**
present study	**subjects (%)**	**219**	34.2	12.8	20.1	32.9	0.5
	DCS (niggle)	**0 (2)**	0	0	0	0 (2)	0
	incidence (%)	**0 (0.9)**	0	0	0	0 (2.8)	0
DCIEM data	**subjects (%)**	**1726**	73.2	7.6	7.9	11.1	0.2
	DCS	**35**	7	0	7	21	0
	incidence (%)	**2.0**	0.6	0	5.1	11	0
	Precordial at FLEX	**N**					
	bubble grade		**0**	**I**	**II**	**III**	**IV**
present study	**subjects (%)**	**117**	22.2	6.8	14.5	46.2	10.3
	DCS (niggle)	**0 (2)**	0 (0)	0 (0)	0 (0)	0 (0)	0 (2)
	incidence (%)	**0 (1.7)**	0 (0)	0 (0)	0 (0)	0 (0)	0 (16.7)
DCIEM data	**subjects (%)**	**1726**	67.4	6.3	6.4	17.7	2.1
	DCS	**33**	3	2	3	21	4
	incidence (%)	**2.8**	0.3	1.8	2.7	6.9	10.8

Comparison of rest and movement (flex) bubble grade data (%-age frequency) and DCS incidence against that of the subset comprising all precordial, air dive data from the DCIEM / Sawatzky data [1,2]. Note DCIEM data taken from table 10.3.9 in [1].
'% age subjects' denotes the percentage of subjects from the total study population (N) to have that respective bubble grade.

this is not the case (0% (2.8% with niggles) vs. 11% DCS incidence for Grade III, or 0 (0.9) vs. 2% overall). Thus, it appears that this profile has a lower DCS risk than might be otherwise indicated by the DCIEM dataset (see Table 6).

Differences in bubble monitoring protocols might have some effect on risk correlations. In the present study, the comprehensive bubble measurement protocol (five-minute intervals for the first 30 minutes, 15 minutes thereafter) allows some confidence that maximum grades were observed: The data describe what is likely to be the full extent of the bubble load post dive. It is unlikely that maximum grades were missed and the bubble load under-reported. In the Canadian study, bubble monitoring commenced generally within 20 minutes post-dive, and was repeated at 30- to 40-minute intervals for at least two hours [1]. In our experience, maximum bubble grades for this 18-msw profile often occur within the first 30 minutes post-dive; this strengthens consensus that bubble measurements should be initiated within 15 minutes post-dive and continue at no greater than 20-minute intervals [12].

The range of bubble grades seen across the studies was wide. Table 4 shows a spread in the frequency of resting bubbling occurring across all of the grades

(KM 0 to IV-), apart from the highest (equal and equivalent to KM IV); no bubbling at this level was observed at rest. The percentage majority of bubbles was split between KM Grade 0 (no bubbles; 34%) and Grade III (33%). Given the increased risk of DCS associated with the highest grades, this spread would seem reasonable. However, it must be noted that the data include both control and intervention dives. If the interventions were successful in lowering decompression stress and thus bubbling, then there could be a higher risk for some types of studies expected to produce a high bubble load. However, examination of the control data alone (Table 3) indicates that the spread of bubbling was similar to the overall results.

With regard to the subject who was treated for neurological DCS, in retrospect, it was unfortunate that no bubble data was collected following his third (symptomatic) dive. However, there was no immediate reason to do so, as having missed his second dive, his bubble data were of no use to the repetitive, multiday dive investigation, and the subject was entirely symptom-free until long after he returned home from the dive.

Profile safety – DCS incidence

Across the 219 dives included in this study, the incidence of diagnosed and treated DCS was zero, though one case associated with Study 7 was observed and treated (as described previously), and there were two shoulder niggles. Even if taking all three of these cases into account over 220 dives the DCS incidence would be only 1.4% (95% CL 0.3% – 3.9%), so the profile appears to be relatively low risk. Some might question this assessment: For example, globally in 2008 DCS incidence rates were around 0.03% [14] – a magnitude lower. However, the 2008 figures consist mainly of recreational dives, where conservatism is key to good diving practice.

All of the exposures included in the present study were "square," i.e., dived to the fullest extent of the profile with no additional level of conservatism added in terms of cutting time short at depth or adding extra decompression time. Essentially, a profile from a table that was designed to be used by military diving professionals was fully "dived out."

This 18-msw dive can be compared to that from U.S. Navy (USN) Table 56, which is slightly less conservative (18 msw / 100 minutes, with a total decompression stop time of 14 minutes as opposed to 22 minutes in RN Table 11). Gerth and Doolette of the U.S. Navy Experimental Diving Unit have stated that the calculated probability of decompression sickness (pDCS) for this Table 56 profile is 3.2% (CI 2.6 – 3.7%) using the BVM(3) model and 3.8% (CI 3.0 – 4.7%) using the NMRI98 model [15], which is much greater than our observed incidence of treated DCS over a reasonable sample number of dives. It should be noted that the models are calibrated with wet, working dives so would probably overestimate the risk for dry, resting dives as in the present study. If the two shoulder niggles are taken as DCS, as some workers would advocate, then our incidence rises from zero to 0.9% (95% CL 0.1% – 3.3%), which is still low in comparison to the U.S. Navy predicted values; but the upper limit of the 95% CL gives an incidence rate of 3.3% – within the range of both models. Indeed, to put this profile in further context, the UK Military Diving Manual [7] refers to it as a "normal exposure where the risk of DCS is negligible."

SUMMARY

The data reported here form a new, relatively large set of post-decompression bubble measurements to compare with existing datasets and models used to assess decompression risk. Overall, observation of both the bubble data and DCS incidence following these 219 dives would seem to suggest that this profile is relatively low risk and would negate the hypothesis that this dive profile produces higher than acceptable post-dive bubble loads. It remains useful for studies where post-decompression bubbles are used to infer DCS risk. ■

Conflict of interest statement

Authors declare no conflicts of interest exist with this submission.

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