Original articles

Risk assessment of SWEN21 a suggested new dive table for the Swedish armed forces: bubble grades by ultrasonography

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Abstract
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Introduction: To develop the diving capacity in the Swedish armed forces the current air decompression tables are under revision. A new decompression table named SWEN21 has been created to have a projected risk level of 1% for decompression sickness (DCS) at the no stop limits. The aim of this study was to evaluate the safety of SWEN21 through the measurement of venous gas emboli (VGE) in a dive series.
Methods: A total 154 dives were conducted by 47 divers in a hyperbaric wet chamber. As a proxy for DCS risk, serial VGE measurements by echocardiography were conducted and graded according to the Eftedal-Brubakk scale. Measurements were made every 15 minutes for approximately 2 hours after each dive. Peak VGE grades for the different dive profiles were used in a Bayesian approach correlating VGE grade and risk of DCS. Symptoms of DCS were continually monitored.
Results: The median (interquartile range) peak VGE grade after limb flexion for a majority of the time-depth combinations, and of SWEN21 as a whole, was 3 (3–4) with the exception of two decompression profiles which resulted in a grade of 3.5 (3–4) and 4 (4–4) respectively. The estimated risk of DCS in the Bayesian model varied between 4.7–11.1%. Three dives (2%) resulted in DCS. All symptoms resolved with hyperbaric oxygen treatment.
Conclusions: This evaluation of the SWEN21 decompression table, using bubble formation measured with echocardiography, suggests that the risk of DCS may be higher than the projected 1%.

Introduction

Decompression tables are of fundamental importance for diving safety and to avoid decompression sickness (DCS). To mitigate the risk for DCS they suggest maximum time and depths combinations. In the Swedish armed forces (SwAF) there are several branches and services with units conducting diving operations. Traditionally the SwAF has adopted the United States Navy (USN) decompression tables and the current tables used in the SwAF, called RMS-dyk 13 tables 1 and 2, are a metric conversion of the USN decompression table revision 6 (USN 6). In 2017 the USN introduced a new decompression table called USN revision 7 (USN 7) and now the SwAF needs to decide if they will adopt this novel table, stay with the current table or choose a third option.

Decompression tables are mainly developed in two ways; either by a probabilistic approach where a database of previous dives is used as a guide to decide which time and depth combinations have an acceptable safety profile or through a deterministic model where the knowledge of gas physiology is used to estimate risk for DCS. In 2021 mathematicians and engineers employed by the SwAF constructed a probabilistic model based on a new database consisting of 2,953 dives which in turn was used to create a deterministic algorithm comprising nine tissue compartments, the details of this work are described in a recent paper.[1] This was then used as a framework to develop a new decompression table called SWEN21 which has a projected risk level of 1% for DCS. To verify a decompression table with an incidence of 1% for DCS by examining the dichotomous outcome of DCS or no DCS with an acceptable confidence interval would require several hundreds of dives to be performed.[2,3] This would be highly time consuming and it is therefore widely accepted to use a proxy, namely intravascular bubbles, usually referred to as venous gas emboli (VGE). Previous studies have shown that an increasing amount of VGE detected in the right side of the heart correlates with the incidence of DCS.[2,4–6] The largest published dataset to date correlating DCS and VGE consists of 3,234 dives and indicates a stepwise increase of DCS risk with 0.1% risk when there are no detectable bubbles up 11.5% risk when there is a large amount of VGE.[4]

Venous gas emboli detection is most commonly performed using Doppler flow signals or by two dimensional (2D) ultrasonic imaging of the heart. The amount of VGE is then classified according to a scale and given a grade. When using the Doppler method the grading systems most frequently used are the Spencer or the Kisman-Masurel scale.[2] When using 2D echocardiography the most common grading system is the Eftedal-Brubakk scale.[7]

Though the risk for DCS when using SWEN21 was estimated to be 1% the true operational risk was not known. To ensure the safety of this novel decompression table validation was needed before implementation.

The aim of this study was to evaluate the safety of SWEN21 through the measurement of VGE in a dive series in a hyperbaric wet chamber. The data in this study are from the validation dive series called ValTKLHN2021.

Methods

ETHICAL CONSIDERATIONS

The Swedish Ethical Review Authority approved the application "*New decompression tables for the Swedish Armed Forces*" (Dnr: 2020-06865). All subjects provided their informed written consent to participate before the start of the study. The study was conducted in accordance with the Declaration of Helsinki.

DIVE PROCEDURES

Eight profiles were identified to examine the safety of SWEN21. These combinations were chosen to test the underlying algorithm of the deterministic model which consists of the nine tissue compartments characterised by a unique halftime and supersaturation quota. The respective time-depth combination resulted in a single compartment being the rate limiting step, or 'leading tissue', from becoming supersaturated in that particular dive. Compartments with halftimes exceeding 40 minutes were not tested at this stage of table development since this was considered too time-consuming.

All dives were performed at the SwAF Diving and Naval Medicine Center (DNC) located on the naval base in Karlskrona in a hyperbaric wet chamber (HAUX 2300). The chamber is a horizontal cylinder 2.6 m in diameter and the desired pressure was set at 0.3 m from the chamber floor. Divers were directed stay at that depth but could deviate to 0.3 m below or 2.3 m above since they swam freely in the water. If divers were deviating from the intended depth the chamber operator directed them to go to the intended depth. Water temperature was 10 degrees Celsius ± 1 degree to mimic typical Swedish operational conditions. Each dive involved two subjects fitted with dry suits, undergarments, wet gloves and the Divator MkIII open circuit breathing apparatus (Interspiro, Taby, Sweden). In the dive profiles with oxygen decompression the gas was supplied via a built in breathing system (BIBS) mask with the diver standing with the head out of water but the rest of the body submerged. Compression and decompression were performed in accordance with USN 7 at 23 metres of seawater (msw)·min^{-1} and 9 msw·min^{-1} respectively. To replicate operational conditions all divers performed low intensity fin swimming during bottom time and decompression. This was accomplished with the diver suspended with an elastic cord to the back off the diving pack or the diver swimming up against the front of the chamber.

ASSESSMENTS

Venous gas emboli in the right heart were recorded by 2D echocardiography and cases of DCS were clinically assessed. Within 5–15 minutes of surfacing VGE measurements were obtained from each subject and thereafter every 15 minutes for at least a total of seven sessions (spanning approximately two hours). The images were obtained with the subject lying in the left lateral decubitus position with the probe positioned for an apical four chamber view. If this position produced an inadequate view the subject was shifted to supine position and the probe positioned in the subcostal position. The 2D cardiac images were obtained using a portable echocrdiography device with a cardiac probe (EDGE II, Fujifilm SonoSite). Harmonic imaging was used since previous studies have shown that this may increase the sensitivity of bubble detection.[7] The VGE grading was done according to the Eftedal-Brubakk scale by two physicians in real time and a grade between 0–5 was given (Table 1). Resting grade was measured first then the flex grade after three vigorous knee extensions with the subject laying in the same position. For the flex grade the highest amount of VGE sustained for two consecutive heart cycles was used for grades of 4 and higher, for grades of 3 or lower the highest amount of VGE sustained for four consecutive cardiac cycles was used. Only the highest VGE grade at any time point from the two conditions (rest or limb flexion) from each man-dive was noted and the median of these values from the respective dive profile was used in this report and will be referred to as 'VGE grade' henceforth. Symptoms consistent with DCS were recorded every 15 minutes in a standardised form

Footnote: * Appendix 1 and 2 are available on DHM Journal's website: https://www.dhmjournal.com/index.php/journals?id=323

Table 1
Eftedal-Brubakk Scale for grading venous gas emboli (VGE)

Grade	Description
0	No bubbles visible
1	Occasional bubbles
2	At least one bubble every four cardiac cycles
3	At least one bubble every cardiac cycle
4	At least one bubble per cm^2 in every image
5	Single bubbles cannot be discriminated

(Appendix 1). If divers showed symptoms a dive physician examined the subject and in a dialogue with the research team decided if the symptoms could be classified as DCS. The reason the research team was involved in the diagnosis of DCS was due to the fact that the diagnosis is based primarily on subjective reporting and many of the clinical observations are ambiguous. Therefore, DCS diagnosis is prone to interobserver variance and there are few accepted objective criteria; this is especially true with cutaneous manifestations according to the clinical experience of this research team. To minimise the risk of misclassification due to subjectivity we decided that classification of DCS in this study would be done in accordance with the definition in Sawatzky's thesis (Appendix 2).[4] The exception was the classification of cutaneous manifestations which was done in accordance with the description by Hartig et al.[8] since we deemed this detailed description was less susceptible to subjective interpretations. The decision to initiate hyperbaric oxygen treatment (HBO) or normobaric oxygen treatment (NBO) was made by the dive supervisor or dive physician.

STUDY SUBJECTS

The subjects were aged 20–59 years and all except two were men. The fitness level varied between subjects; some were exercising an hour per week whereas others did over 10 hours per week. The majority were exercising 3–4 hours per week. Most subjects, with the exception of seven relatively recent graduates from SwAF diving school, had extensive experience with diving with several hundreds of logged dives in the military context. Many were also recreational divers. Two of the divers reported that they previously had DCS, during this series none of them experienced new events of DCS. All divers met the SwAF fitness to dive standard. Exclusion criteria were diving within the preceding 48 hours to avoid residual nitrogen load which could result in more bubble formation, ongoing infection and physical training the last 24 hours as previous work has shown this could lower bubble grade.[9,10] Subjects were recruited by mail inquiry to the respective diving units in the SwAF by the staff of DNC. Participation was voluntary and that participants could discontinue the study at any time without any explanation, and neither participation nor discontinuation would affect their military career.

STATISTICAL ANALYSIS

Venous gas emboli grades are ordinal data. Median and interquartile range (IQR) of the VGE grades were calculated for each separate diving profile, all direct ascent dives, all decompression dives and all the dives combined.

To estimate the risk of DCS we implemented the method described by Eftedal.[3] In this approach the risk of DCS after diving a specific profile T was modeled as

$$P(DCS \mid T) = \sum_{i=0}^{5} P\,(DCS \mid BG_i)P(BG_i \mid T) = \sum_{i=0}^{5} p_i\, q_i(T)$$

where $p_i = P(DCS \mid BG_i)$ was the risk of DCS when the maximum observed bubble grade was i, and $q_i(T) = P(BG_i \mid T)$ was the probability of developing bubble grade i after dive profile T. The probabilities p_i and $q_i(T)$ were treated as random variables, whose probability distributions were estimated from a prior and empirical data using Bayesian statistics. A Monte Carlo simulation ($n = 500{,}000$ samples) was used to approximate the resulting probability distribution of $P(DCS \mid T)$ and determine a 95% credible interval.

The inputs to this algorithm were:

1. A prior distribution for the probabilities p_i. The prior suggested by Eftedal et al.[3] in their Equation 4 was used, namely a point mass of weight 0.1 at each of the endpoints $p_i = 0$ and $p_i = 1$ and the remaning mass distributed uniformly.
2. A prior distribution for the probabilities q_i. The prior suggested by Eftedal et al.[3] in their Equation 5 was used, namely a Dirichlet distribution with parameters: $\gamma = [0.5051, 0.3503, 0.3132, 0.6264, 0.2785]$.
3. A dataset $D_{BG \to DCS}$ of dives with recorded bubble grades and DCS outcomes. These empirical data, together with the prior distributions of p_i were used to compute a posterior distribution for each p_i. For this input we used two different datasets:
   (a) The data from Sawatzky, cited by Eftedal et al.[3] in their Table 1.
   (b)The data cited by Doolette in his Table 2.[11]
4. A dataset $D_{T \to BG}$ of dives performed according to a specific dive profile T with recorded bubble grades. These empirical data, together with the prior distribution of q_i were used to compute a posterior distribution for q_i. For this input we used the dives from the present trial.
5. We assumed the correspondence between VGE grades from the Doppler data obtained by Sawatzky, which was graded with the Kisman Masurel scale, and our own VGE data, graded with the Eftedal-Brubakk scale, to be zero to zero, one to one and so forth. The same correspondence was assumed with the VGE grades from Doolette's data, graded according to Naval Experimental Diving Unit

Table 2

Venous gas emboli (VGE) grades (Eftedal-Brubakk scale) for SWEN-21 from the validation dive series ValTKLHN2021; # decompression with air (see Appendix 3 for respective decompression schedules); ¤ decompression with oxygen (See Appendix 3 for respective decompression schedules); [a] numbers of divers with cutaneous manifestation of diving not to be classified as decompression sickness (DCS), e.g., redness and pruritus; [b] diver who received prophylactic NBO because of arterial bubbles; HBO – hyperbaric oxygen treatment; IQR – interquartile range; min – bottom time minutes; msw – metres of seawater; NBO – normobaric oxygen treatment

Dive profile msw / min	*n* dives	Median (IQR) VGE grade rest / flexing	*n* DCS	DCS-type (peak VGE grade of individual DCS cases)	*n* cutaneous stress[a]	Treatment
Direct ascent profiles						
All direct ascent profiles	100	3 (1–3) / 3 (2–4)	2	2 musculoskeletal	1	2 HBO 1 NBO
18 / 59	20	3 (2–3) / 3 (3–3.5)	2	Shoulder pain (3) Hip pain (4)		2 HBO
24 / 33	20	3 (1–3) / 3 (2–4)				–
33 / 17	24	3 (2–3) / 3 (3–4)			1	1 NBO
39 / 12	20	3 (1.5–3) / 3 (1.5–4)				–
45 / 8	16	2 (1–3) / 3 (2–3)				–
Decompression profiles						
All decompression profiles	54	3 (2–4) / 3 (3–4)	1	1 neurological	8	1 HBO 2 NBO
39 / 20#	22	3 (2.5–4) / 3.5 (3–4)			1	1 NBO
51 / 10#	16	2.5 (1.5–3) / 3 (2–4)	1	Sensory loss leg and torso (4)		1 HBO
57 / 15#	8	4 (3.5–4) / 4 (4–4)			5	1 NBO[b]
57 / 15¤	8	3 (1.5–3.5) / 3 (2–4)			2	–
All profiles combined						
All profiles	154	3 (2–3) / 3 (3–4)	3	1 neurological, 2 musculoskeletal	9	3 HBO 3 NBO

(NEDU) 2-D echocardiography VGE scale, namely zero to zero, one to one and so forth. Both the Kisman-Masurel and the NEDU 2-D scales consist of grades 0–4 whereas the Eftedal-Brubakk consists of grades from 0–5. In the present study we saw no VGE of grade 5 and to the authors' knowledge this has only been seen in animal studies. Therefore, we did not consider this grade or its corresponding value in the other grading scales.

Results

A total of 154 dives were performed by 47 divers. There were three cases of DCS. Two of the events were classified as musculoskeletal (joint pain) and the third was classified as neurological with symptoms in the form of sensory loss in a leg and parts of the torso. All DCS cases were treated with HBO according to the US Navy Treatment Table 6 with complete resolution of findings and symptoms. One of the divers who experienced DCS after a 18 msw / 59 minute dive showed arterial bubbles later in the series after a 57 msw / 15 minute dive with air decompression. Follow up medical examination showed that this individual has a patent foramen ovale (PFO). The diver who developed neurological DCS was upon examination also shown to have a PFO. Nine divers showed cutaneous manifestations in the form of red skin and or pruritus, none were classified as DCS but instead as decompression stress.

Three divers received prophylactic treatment with NBO by the attending dive physician, two because of non-DCS cutaneous manifestations and one because of visible arterial bubbles on ultrasonography. The two divers who developed musculoskeletal DCS after the 18 msw / 59 minute profile received NBO at 105 minutes after surfacing, prior to HBO-treatment. Receiving NBO may lower VGE grades but since all the divers in the above-mentioned cases, except one, had a grade of 4 in at least in one of the conditions these were kept in the Bayesian DCS risk calculations. The exception was one diver in the 18 msw / 59 minutes profile who had a VGE grade 3 prior to NBO, he was excluded from the

Table 3

Distribution of individual peak venous gas emboli (VGE) grades (Eftedal-Brubakk scale) by dive profile; # decompression with air (see Appendix 3 for respective decompression schedules); ¤ decompression with oxygen (See Appendix 3 for respective decompression schedules); min – bottom time minutes; msw – metres of seawater

Profile msw / min	*n* dives	VGE grade 0	1	2	3	4
18/59	20	1	2	1	12	4
24/33	20	0	4	2	8	6
33/17	24	0	2	2	11	9
39/12	20	2	3	1	6	8
45/8	16	0	3	4	6	3
39/20#	22	0	0	0	11	11
51/10#	16	1	1	4	5	5
57/15#	8	0	0	0	1	7
57/15¤	8	0	0	3	2	3
Total	154	4	15	17	62	56

Table 4

Estimated risk of DCS for the different dive profiles using Bayesian statistics; * a database of dives correlating VGE grade with risk of DCS; # decompression with air (see Appendix 3 for respective decompression schedules); ¤ decompression with oxygen (See Appendix 3 for respective decompression schedules); CI – credible interval; min – bottom time minutes; msw – metres of seawater

Dive profile msw / min	$D_{BG \to DCS}$* with Sawatzky's dataset[4] Estimated DCS risk %	95% CI	$D_{BG \to DCS}$* with Doolette's dataset[11] Estimated DCS risk %	95% CI
Direct ascent profiles				
All direct ascent profiles	7.6	5.0–10.5	5.3	3.5–7.2
18 / 59	7.2	4.5–10.2	5.6	3.4–8.0
24 / 33	7.3	4.3–10.6	5.1	3.2–7.2
33 / 17	8.5	5.2–12.1	5.7	3.7–7.9
39 / 12	7.7	4.2–11.6	4.7	2.9–6.8
45 / 8	5.9	3.3–8.8	4.7	2.9–6.8
Decompression profiles				
All decompression profiles	9.3	5.6–13.3	5.5	3.6–7.6
39 / 20#	10.1	6.2–14.4	6.2	4.0–8.6
51 / 10#	6.8	3.6–10.4	4.7	2.8–6.7
57 / 15#	11.1	5.4–17.5	5.3	2.8–7.9
57 / 15¤	7.0	3.1–11.3	4.7	2.6–6.9
All profiles combined				
All profiles	8.3	5.3–11.5	5.4	3.6–7.3

Bayesian DCS risk calculation because the NBO might have lowered his VGE grade.

The median VGE grades for each dive profile are shown in Table 2. The majority of the depth-time combinations resulted in a grade of 3 both at rest and after flexing which was also the median of the SWEN 21 table as a whole. The exceptions were the 57 msw / 15 minutes profile with decompression on air which resulted in a median bubble grade of 4 at rest and after flexing (IQR 3.5–4 and 4–4 respectively), the 51 msw / 10 minutes profile with air decompression which at rest resulted in median grade 2.5 (IQR 1.5–3) and the 39 msw / 20 minutes profile which after flexing resulted in median grade 3.5 (IQR 3–4). The distribution of individual VGE grades per profile can be viewed in Table 3.

The estimated DCS risk for the different dive profiles is shown in Table 4. Using the data from Doolette[11] correlating VGE grade and DCS outcome as inputs to the Bayesian model suggests the overall risk of DCS using SWEN 21 is 5.4% (95% CI 3.6–7.3); varying between 4.7–6.2%

risk between the different profiles with the decompression profiles having slightly higher risk. Using the Sawatzky data[4] as inputs suggests a DCS risk that is substantially higher with an overall risk of 8.3% (95% CI 5.3–11.5) and varying between 5.9–11.1% risk between the different profiles. Once again the decompression profiles have a higher estimated DCS risk.

Discussion

The main finding in this study is that according to VGE grades the estimated risk of DCS when using SWEN21 may be higher than the projected 1%. Using Doolette's data as input in the Bayesian model the risk of DCS when using SWEN 21 is around 5% and all of the profiles have a credible interval over 1% which indicates that the DCS risk is likely higher than this. Using the data from Sawatzky as input the overall risk is around 8% with all credible intervals well above 1% which also indicates that the risk is higher than that. The advantage of using the Sawatsky dataset is that it is large and could therefore be assumed to more accurately correlate VGE grade to DCS risk. The downside is that dive conditions and VGE grading might not be consistent with the present trial. The experiments by Sawatzky and colleagues at the Defense and Civil Institute of Environmental Medicine (DCIEM) were done during the 80s and 90s with Doppler flow signals.[4] In our study we used 2D echocardiography. Previous studies have confirmed that there is a good correlation between Doppler flow signals and 2D cardiac imaging, but new advances in echocardiography technology may have made 2D imaging more sensitive in detecting VGE.[7,12] In Sawatzky's material 47% of 1,726 dives produced no detectable bubbles[4] whereas in our study absence of bubbles was found in only 2.5% (4/154) of the dives. This difference may be attributed to confounders such as different depth-time combinations, age and fitness levels of the subjects, all which influence bubble grades, but it may also be due to contemporary technology being more sensitive in detecting bubbles.[2] It might therefore be more suitable to use a more recent dataset like the one from Doolette which also uses 2D ultrasound imagine to grade VGE.[11] The DCS risk is substantially lower using this dataset but still well over 1%. A limitation in using Doolette's dataset is that the VGE grading scale used has not been validated against the Eftedal-Brubakk grading system. In the Bayesian calculation we assumed that these two ordinal scales directly correlate but this may not be the case and therefore the corresponding DCS risk may not translate between the two datasets.

Both the Sawatzky and Doolette datasets used in the Bayesian calculation measured VGE less frequently compared to our dataset. The Sawatsky study made the first measurement 30 min after surfacing and thereafter every 40 min. In the Doolette study the first measurement was done 30 min after surfacing and then at the two-hour mark. In our study four monitoring sessions were completed within the first hour and at least three during the second hour which generated greater temporal resolution. The mean time to reach peak VGE grade in our study was approximately 20 minutes and the 10 minutes delay in first measurement when compared to the Sawatzky and Doolette data could in theory lead to transient early peak VGE grades having been missed which may alter the indicated DCS risk. Other experts in the field have suggested the first monitoring session should be done within 20 min from decompression and that 40-min intervals between measurements may be too sparse and risk underestimating VGE grades.[2] If we examine our VGE grades at 30, 70 and 110 minutes, the same measurement frequency as in Sawatzky's data, and exclude all other measurements, a total of 24 VGE grades were lowered by one or two points. When excluding all measurements except the ones closest to 30 and 120 minutes, as in the Doolette dataset, a total of 32 VGE grades were lowered by one or two points. Using these lower VGE grades from the Sawatzky data in the Bayesian model all of the profiles, except two that were unchanged (51 msw / 10 min and 57 msw / 15 min with oxygen decompression), lowered their relative DCS risk in the range of 4–15% (see Appendix 4). The same analysis with the lowered VGE grades from the Doolette data showed a relative risk reduction in six of the nine profiles, in the range of 2–11%. However, two profiles, 39 msw / 12 min and 57 msw / 15 min with air decompression, showed an increased risk in DCS with 6% and 4% respectively (see Appendix 4). This is explained by the fact that in the original Doolette dataset the risk for DCS is lower with a VGE grade of 4 (5%) than with a grade of 3 (7%).[11] Therefore, the lowering of VGE grades from 4 to 3 in any profile leads to higher estimated DCS risk. This explains why the tendency for DCS risk reduction was more pronounced in the reanalysis of the Sawatzky dataset than in the Doolette dataset. The overall tendency to lower the DCS risk assessments with a reduced measurement frequency would have likely reduced our own DCS risk estimates with the Bayesian approach even further if our own dataset was larger.

Assuming the true incidence of DCS when using SWEN21 is 1% we can, with the help of binominal statistics, calculate that there is a 95% probability that the number of DCS cases would be in the range of 0–3 when performing 151 dives (the three divers who received prophylactic NBO were excluded from this calculation because NBO may alter the risk of developing DCS). Using the estimated risk suggested from Sawatzky's data (8.3%) with the same assumptions there is a 0.12% chance that there would be three or fewer cases of DCS. Using the suggested DCS risk from the Doolette data (5.4%) the probability of seeing three or less cases of DCS is 3.4%. This discrepancy in risk suggested by binominal statistics compared to the Bayesian model, especially in the case of the Sawatzky's dataset, could in part be explained by the fact that the reference material, which links VGE grades and DCS, is overestimating the risk of DCS at the respective VGE grade. Data supporting this line of reasoning comes from NEDU where a larger dive series (n = 96) evaluated a similar dive profile (40 msw / 20 min, 9 min deco at 6 msw) to one in the present trial (39 msw / 20 min, 13 min decompression at 6 msw) resulting in similar VGE grades but with a low incidence of DCS.[13] A prerequisite for estimating DCS risk for a dive profile by means of VGE measurement is that a relation between VGE grade and DCS risk can be derived from a larger dataset of dives. This approach is based on the assumption that the risk of DCS for a diver with a given VGE grade is independent of the dive profile. Furthermore, it is assumed that measurements of VGE grades are so consistent that they can be compared between different datasets which may or may not be true. The two different datasets used in this study correlating DCS risk to VGE grade indicate widely different risk from one another possibly indicating that the VGE measurements are not comparable between the two datasets. Experts in the field of decompression theory question the validity of inferring DCS risk from VGE grades and have shown in big data sets that VGE grade is an imperfect surrogate for DCS risk.[11] Together there are several factors that make the estimate of DCS risk from VGE grade uncertain and therefore these data should be interpreted cautiously.

Strengths of this study includes that it was a large series done in a controlled and standardised way with frequent measurements graded by two diving physicians, one of whom has several decades of experience in this field of research. A potential limitation was that the test population may not fully be representative of operational divers in the SwAF. The divers in this validation series tended to be older than operational divers and higher age is a factor that may cause a higher bubble grade and an increased risk of DCS.[10] In summary, this warrants further validation of SWEN21 to ensure its safety.

Conclusion

This evaluation of the novel SWEN21 dive table, using VGE formation measured with echocardiography suggests that the DCS risk may be higher than the projected 1%.

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