CCO Ltd

Diving management studies
Study No 11

About pre-dive conditioning and commercial diving

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Important Note

This study is written to inform people interested in diving activities of the elements to take into account to prepare for successful operations. However, implementing the procedures discussed is the reader's sole responsibility.

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1 - Purpose

Current decompression procedures aim to control the risks linked to Decompression Sickness (DCS) by managing factors such as the dive duration, the depth, the ascent rate, and the duration of the stops. However, in the paper *"Preconditioning Methods and Mechanisms for Preventing the Risk of Decompression Sickness in Scuba Divers: A Review"*, doctors Emmanuel Gempp & Jean-Eric Blatteau say that clinical data supporting the importance and the role of each factor on Decompression Sickness (DCS) development are lacking due in part to the great inter/intra-variability between individuals regarding susceptibility to DCS. They also say that based on their clinical experience and Divers Alert Network (DAN) statistics, most injured divers presenting neurological DCS (75%–90%) followed their dive profile and did not performed inadequate decompression schedules, which puts forward the notion that conservative dive profiles are no guarantor of protection against DCS and that novel means are required for DCS prevention.
The fact that diving time and nitrogen pressure are not the only determinants of Vascular Gas Embolisms (VGE) formation and that factors such as the variation between individuals and other not fully clarified phenomenons is taken into account by many other scientists. For example, doctors Peter Germonpré & Costantino Balestra confirm these points in their study *"Preconditioning to reduce decompression stress in scuba divers"*. For these reasons, new concepts still under evaluation have been developed to explain the production of Vascular Gas Embolisms (VGE), such as the generally admitted assumption that bubbles form from pre-existing gaseous nuclei, and that these initially unstable nuclei may be trapped in intercellular hydrophobic crevices on the endothelial surface or be coated by surface-active molecules like surfactant, platelets, or proteins and thus stabilized by these processes before being released into the bloodstream. These mechanisms of nuclei formation are still debated by scientists with also the role of body substances such as Nitric Oxide (NO), an omnipresent intercellular messenger, modulating blood flow and neural activity, which is thus involved in vasodilatation. That opens to studies on chemical reactions and drugs that may be used to interfere in these phenomenon and be used to control the production of Vascular Gas Embolisms (VGE).
In the paper called *"Static Metabolic Bubbles as Precursors of Vascular Gas Emboli During Divers' Decompression: A Hypothesis Explaining Bubbling Variability"* Jean-Pierre Imbert, Salih Murat Egi, Peter Germonpré, and Costantino Balestra make a status of the research ongoing and propose solutions that will probably result in new decompression tables in the near future. As there is, for the moment, no table integrating these new concepts in a public release for commercial diving, we continue to use tables such as DCIEM or COMEX MT 92 that, although they are not integrating these new concepts, have proved to be and continue to be efficient means of control. However, some elements from the studies mentioned above can be implemented to improve these procedures. Among the solutions investigated to improve decompression, the authors of this document insist on the benefits of "pre-dive conditioning", which refers to experimental studies made to demonstrate that exercises, oxygen, or substances uptake before the immersion have beneficial effects on decompression. These beneficial effects are assumed to result from eliminating nuclei by physical processes or/and chemical reactions. To highlight the advantage of the pre-dive conditioning, we can refer to a paragraph of this study where the authors remember experiments made by doctors Gennser and Al that concluded that five weeks of bed-rest significantly increased bubble grades after decompression. The reasons given to explain these results are the following:

- Bedrest conditions are associated to minimal activity and therefore to a minimal metabolism. The consequence is that the initial Static Metabolic Bubbles (SMB) volume in the divers prior to the dive was maximal.
- The lack of exercise reduces vibrations and it is likely that most of the available Active Hydrophobic Spots (AHS) were populated by SMB.
- After a bedrest, the divers started the dive with a high density of SMB with a maximal volume that favored higher grades of detected VGE.

Scientists have successfully tested the pre-dive conditioning solutions listed below on humans.

- Endurance exercise:
  This process consists of exercises requiring 70 to 90% of maximum heart rate performed before the dive. Note that the maximum heart rate is often calculated with the formula "220 minus the age of the person" on humans.
- Hydration:
  This concept is based on the fact that it has long been suggested that dehydration may increase the risk of Decompression Sickness (DCS) and that experiments have been made on animals that correlate this fact.
- Heat exposure:
  This concept leans on papers that demonstrated that moderate dehydration resulting in stroke volume reduction induced by a predive exercise could decrease venous circulating bubbles in divers.
- Oxygenation:
  These procedures are based on the assumption that oxygen breathing before diving eliminates pre-existing gas micronuclei before they can grow into bubbles. The proposed mechanism is based on the ability of oxygen to replace nitrogen in the nucleus by diffusion. The reduction of oxygen pressure after switching from oxygen to air could enhance the consumption of oxygen from the nucleus, thus eliminating it completely.
- Vibration:
  This procedure consists of submitting the diver to sessions on vibrating mattresses sold to all public in shops. The effects expected are similar to those obtained with predive exercise, but with better results.
- Jumping:
  This technique aims to provoke blood displacement and muscular contractions to dislodge VGE nuclei. The method selected to obtain the expected results involves jumping on a mini trampoline.

- Specific substances uptake:
  This terminology refers to drugs or food that can be used to control chemical reactions linked to decompression, such as nitric oxide (NO) production.

The processes of these experiments are described in papers available on the "Diving and ROV Specialists.com" website and through recognised scientific documents publishers.

Considering that scientists are very imaginative, other procedures may have been and will be tested. It is, thus, difficult or impossible to publish all the documents that have been published regarding the topics discussed. However, the above strategies already give us a view of the various solutions that can be implemented to reinforce existing decompression processes.

We, nevertheless, need to take into account the fact that these reinforcement processes are experimental and that, despite the positive results obtained, they may not apply to commercial diving operations due to implementation issues, and the fact that the procedures described have been tested with military and sportive divers, who used Self-Contained Underwater Breathing Apparatus (SCUBA) so initially thought in the function of the concepts to be tested and according to the available methods to experiment with them. Even though the effects on the body triggered by diving activities are the same whatever the technique used, occasional military and sportive diving operations are organized differently from the stringent procedures we have to put in place for the intensive operations we commonly manage in commercial diving. For these reasons, it is essential to know the main techniques applied for commercial "surface-supplied" diving operations and highlight their difference from the processes in place for sportive and military operations using SCUBA. A reminder of the procedures we use is provided before the brief descriptions of the various experiments undertaken for this aim and to understand the comments made in the discussions and what is needed for commercial diving.

Thus, the purpose of this study is not to evaluate whether the procedures described in the papers taken into consideration are beneficial for decompression because the authors of these documents already did it. It is not also to question the validity of these studies as competent people have already done that. It is only to highlight what has been done regarding pre-dive conditioning and investigate which procedures can be implemented to improve the existing decompression models using a conservative approach to avoid playing the sorcerer's apprentice. It is also to suggest what diving companies could do to support scientists in this kind of research that can be profitable for the diving community, particularly for them.

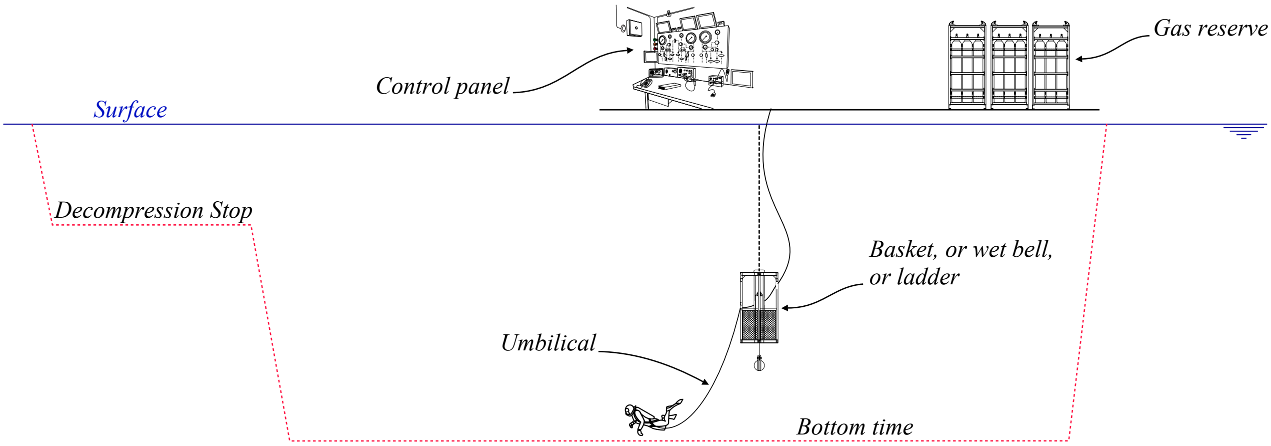
An important point to highlight is that all these experiments have been performed according to the *"Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects"*, published by the World Medical Association. This document, available for download on "Diver & ROV specialists.com", was developed by the World Medical Association (WMA) in response to the atrocities made by Nazis and Japanese scientists in concentration camps before and during the 2nd war, and also several cases of abuse made by companies and scientists working in experimental medicine. It is today considered a reference regarding the protection of volunteers on whom new medical processes are tested. That means that only healthy divers have been selected, their health has been carefully monitored, and they have never been exposed to dangerous dive profiles.

2 - Remembering how commercial surface-supplied diving operations are organized

It is essential to remember how surface-supplied commercial diving operations are organized to understand the purpose of this study.

2.1 - Quick description

"Surface supplied diving procedures", also called "Surface orientated diving procedures" by IMCA (International Maritime Contractor Association) and NORSOK (Norsk Sokkels Konkuranseposisjon - Norway), are incursion diving methods where the diver is deployed from the surface using systems such as ladders, baskets, and wet bells, and is supplied by gas using an umbilical by compressors and gas tanks, stored on the deck of the ship or the facility from which the diving operations are organized.
This technic provides the advantage that the dive duration is not limited by the gas reserves the diver can carry and that he is not obliged to carry extra bottles. Also, even though the umbilical slightly restricts the diver's movements, it allows him not to be lost in the water and always return to its means of deployment. It also allows to keep him at a safe distance from identified hazards and not go too far from his means of deployment. In addition to breathing gas, the umbilical carries voice communications, video signals, depth control systems, electricity for the diver's light, and hot water for heating him in case of operations in cold water.

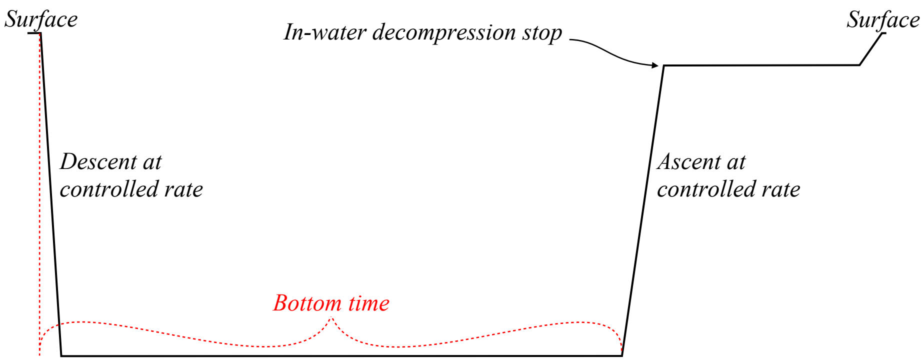


Having substantial gas reserves and heating systems to control the cooling-off of the diver gives the possibility of performing long dives. However, the diver will be physiologically limited by the decompression to perform, and fatigue. For these reasons, statutory instruments of countries and guidelines published by professional organizations provide limitations linked to the depth, the gas breathed and the system of deployment used. Note that surface supplied operations do not require complex equipment like methods such as saturation diving.
Among the regulations that influence the organization of the operations, note that the minimum size of a surface supplied diving team using air or nitrox should be 6 people:

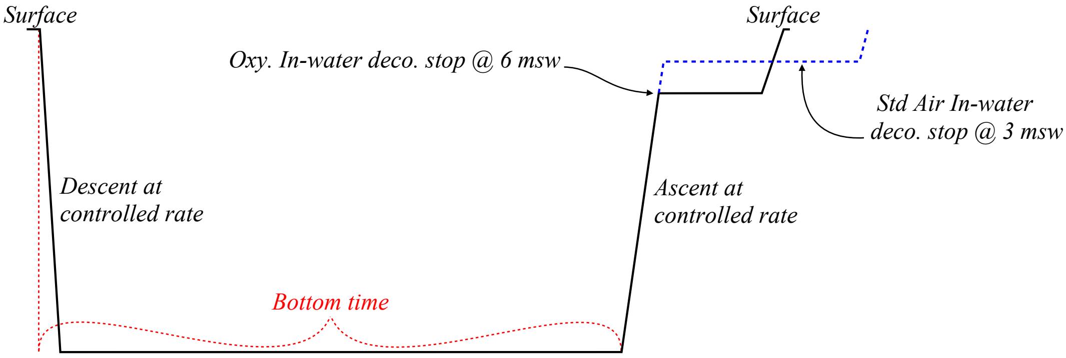
- 1 diving supervisor: He is in charge of the ongoing dive and the shift
- 1 diver at work: He works under the responsibility of the diving supervisor who manages his decompression.
- 1 diver’s tender: He is responsible for dressing the diver and controlling his umbilical.
- 1 standby diver: He is responsible for rescuing the diver if required. He stands by on deck, ready to dive.
- 1 standby diver’s tender: He is responsible for dressing the standby diver and controlling his umbilical.
- Most organisations require a system technician in addition to the minimum team.

As mentioned above, the decompression of the diver is managed by the diving supervisor. Tables approved for working underwater by statutory instruments are used for this purpose, such as, for example, MT 92 COMEX or DCIEM tables. Thus, personal diving computers are not used in commercial diving. The following procedures are commonly used for surface-supplied operations using air or nitrox:

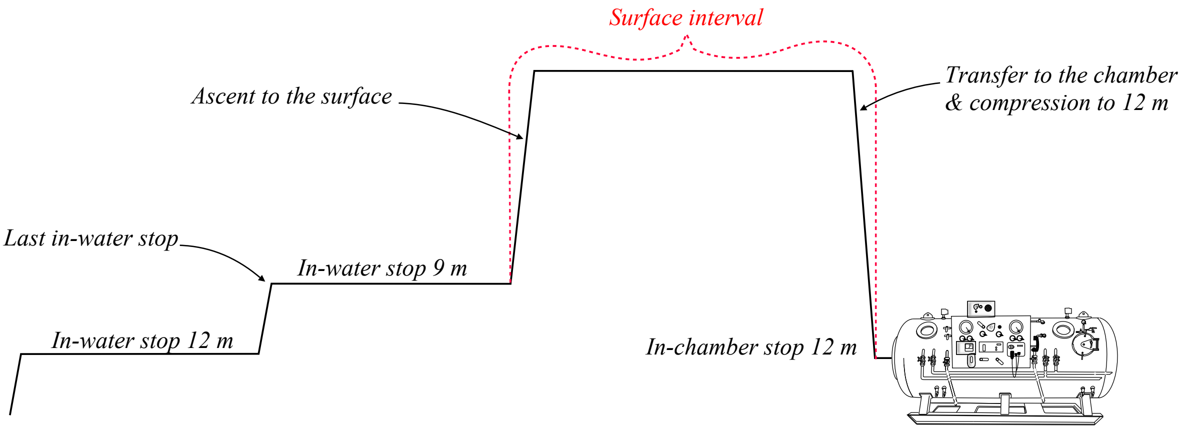
- “Standard Air Tables” are in-water decompression tables similar to those used for the experiments related in the previous chapter. Thus they consist to descending and ascending at controlled rates and performing the required decompression stops in the water.



- "In-Water Oxygen" tables are based on the same procedure as "Standard Air" tables, except the last stop is performed at 6 m with 100% oxygen (some tables have their final stop at 9 m). That results in reducing the decompression time. As an example, for a dive of 30 minutes at 30 msw, with the COMEX MT 92, the oxygen in-water stop is 5 minutes instead of 10 minutes with Standard air.

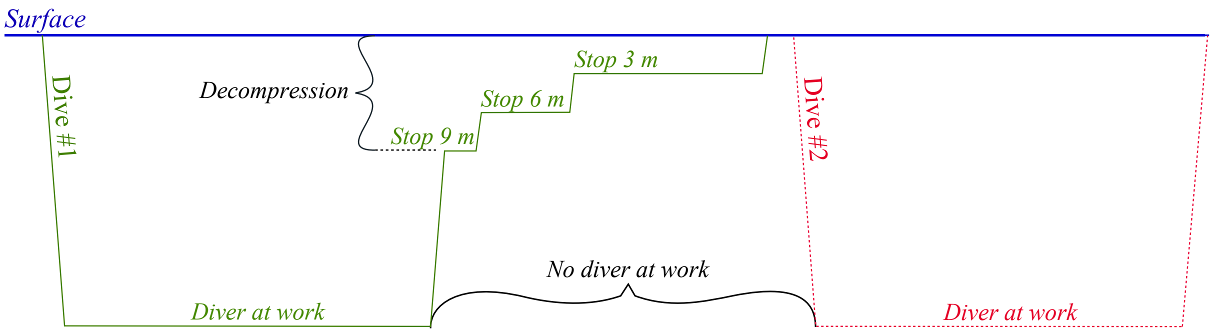


- "Nitrox Procedures" Consist of partially replacing the nitrogen of air with oxygen. As a result, the decompression for the actual depth is performed according to the Equivalent Air Depth (EAD), and less stop time is to be performed. As an example, for a dive at 25 m using a mix of 40% oxygen, the equivalent depth is 18 m, which results that, for 60 minutes bottom time, the decompression time is 6:15 minutes with nitrox instead of 38:45 minutes with air using the table MT92.
  It must be noted that the last USN manual sets the maximum PPO2 at work to 1.4 ata and that organizations such as the Diving Advisory Medical Committee (DMAC) or IMCA have also reduced their maximum PPO2 value to this limit. That has the effect of reducing the efficiency of this procedure.
- "Surface Decompression" is a procedure that consists of partially decompressing the diver in the water up to the in-water stop at 9 m, then recovering him to the surface and transferring him to the chamber to recompress him to 12 m (MT 92 & DCIEM) or 18 m (USN), and complete the decompression. Depending on the table, the surface interval (time from leaving the 9 m stop to reach the 12 m stop in the chamber) is limited from 3 to 7 minutes. This procedure is based on the fact that the phenomenons that trigger a decompression accident do not start immediately, and there is a short period during which the diver has the time to be transferred to the chamber to treat the problem and complete the decompression. As a result of the interrupted decompression process, the decompressions using this procedure are longer. For example, for a bottom time of 30 minutes at 30 msw, the decompression time is 20:30 minutes instead of 12:15 minutes with the "Standard air" table. This procedure has the advantage that the diver is removed from the water. On the other hand, it has numerous inconveniences linked to the surface transfer as the decompression process is not terminated during this phase.

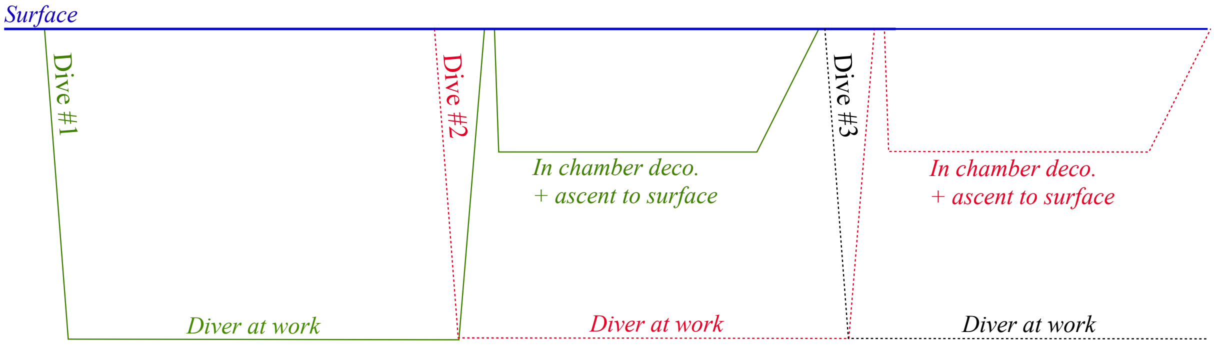


The diving operations are organized according to the work to perform and the number of divers available for this work, which is usually linked to the financial envelope assigned to the project.

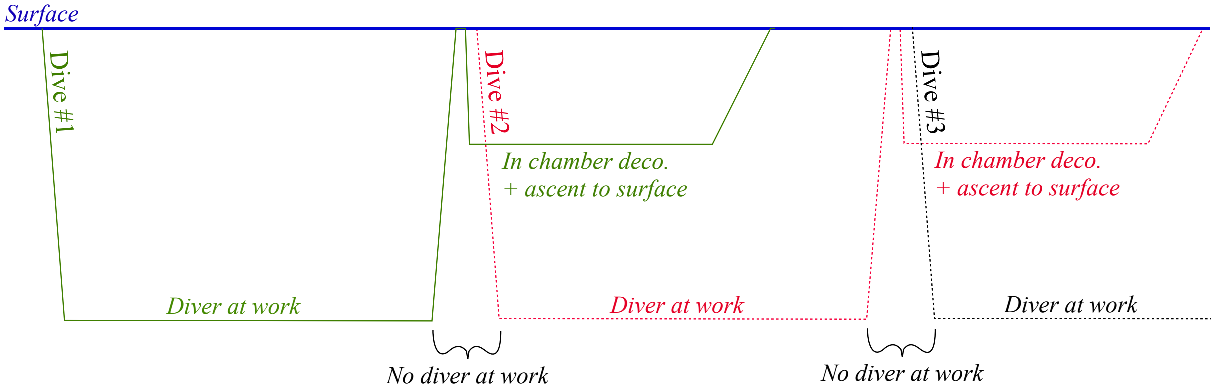
- "Non-continuous diving" involves launching the diver when the previous diver has completed his stops.
  It has the inconvenience that no work is performed underwater during the decompression time, in addition to the fact that more time is lost to launch the next diver. These procedures are often applied when there are not enough divers to perform more intensive operations or when the work requires only episodic dives.



- "Real continuous diving" is a procedure where the diver is replaced as soon as his bottom time is completed. This procedure allows having continuously one or two divers at work. Two separate teams and thus their launching and recovery systems (LARS) are required to implement this procedure efficiently, so that team #2 is launching his diver while the diver of team #1 is in the latest minutes of his bottom time. Surface and in-water decompression procedures can be applied. Depending on the working depth, the implementation of this procedure may involve large teams.



- "Pseudo continuous diving" is a procedure where the diver starting his dive is launched when the diver previously on the job begins his decompression. It has the effect that there is a gap where there is no diver at work between two dives. The gap duration depends on the decompression procedure (in-water or surface deco.), the table selected (MT 92, DCIEM, USN, etc..), and also the equipment available and used. This procedure is usually implemented when there are not sufficient personnel and equipment to implement the "Real continuous diving" procedure.



Reinforcement procedures are commonly implemented by diving teams:

- The "Decompression safety procedure", previously called "Jesus factor", is an old concept based on the fact that a table is developed for a determined population of divers, which does not always correspond to the divers operating on the job site. This procedure was initially implemented because most tables used during the 60s and 70s were initially designed for military divers which resulted in numerous decompression accidents. This "Jesus factor" is described in detail in the document "*The incidence of decompression sickness arising from commercial offshore air-diving operations in the UK sector of the North sea during 1982/83"* issued in December 1997 by doctors Shields and Lee.
  Even though the tables currently used, such as MT 92 or DCIEM, have provided considerable improvements, this procedure that consists in adding bottom time or switching to the next deeper depth continues to be applied by numerous supervisors and is mandatory with some companies because databases have demonstrated that the tables need to be sometimes reinforced according to the tasks performed, the environmental conditions, and the age of the diver. In addition to preserving the divers' health, many companies ensure that no decompression sickness happens because such an undesirable event results in incident reports that may damage their reputation. This point is not the most glorious, but it must be taken into account.
  Safety procedures are officially introduced in some tables. It is the case of the COMEX /MT 92, where it indicated the following: *"When diving or working conditions are difficult, the risk of a decompression accident is higher. It is an established fact that poor physical condition, nervous tension, poor visibility, cold and accumulated fatigue after weeks of intensive diving, predispose a diver to decompression sickness. Similarly, a current, uncertain depth control and poor sea conditions make decompression procedures difficult to follow and thus increase the risk of a decompression accident. All these factors must be taken into consideration when a decompression table is chosen. In the case where diving conditions are such that they may adversely affect decompression safety, the next longest time on the bottom in the table should be used in order to give the divers an additional margin of safety"*.
  It is also the case of the Norwegian tables where it is said in chapter "prevention for decompression illness" : *"If there are circumstances increasing the risk for decompression illness, the decompression should be more conservative than prescribed by the tables. Especially this is true if multiple risk increasing factors are present and for dives with bottom times bordering the maximum allowed bottom time. In such cases the standard air decompression tables should be used more conservatively by decompressing according to a table time one or two steps longer than otherwise."*

Note that Norwegian tables also proposes a procedure to assess the individual risk factors of the diver and reinforce his decompression accordingly.
This concept has also been adopted by manufacturers of diving computers designed for scuba diving that provide the possibility to reinforce the basic decompression profile.

- Another commonly implemented reinforcement procedure is that many companies have adopted the UK-HSE bottom times limits instead of using maximum operational limits based on the repeat group of the tables. These recommended limits, also adopted by organizations such as the International Oil & Gas Producers (IOGP), are those of the report "*The incidence of decompression sickness arising from commercial offshore air-diving operations in the UK sector of the North sea during 1982/83"* issued in December 1997 by doctors Shields and Lee. This report can be downloaded through the link: http://diving-rov-specialists.com/index_htm_files/scient-b_25-shields.pdf and through the UK-HSE website. It provides the following bottom time limits.

Depth		***Bottom times limits***
Metres	***Feet***	***SD & In water***
0 - 12	*0 - 40*	*240*
15	*50*	*180*
18	*60*	*120*
21	*70*	*90*
24	*80*	*70*
27	*90*	*60*
30	*100*	*50*
33	*110*	*40*
36	*120*	*35*
39	*130*	*30*
42	*140*	*30*
45	*150*	*25*
48	*160*	*25*
50	*164*	*20*

- A well-known cause of accidents is the fatigue of the supervisors and the divers. For this reason, it is recommended to have two supervisors on shift at the same time and not limit the personnel to a minimum. As a result, a supervisor can relax away from the dive station after the dive he has completed and then prepares for the next dive and help his colleague who is monitoring the ongoing dive. This procedure is mandatory when continuous diving is organized, and the teams are doubled.
- An additional reinforcement is that some diving organizations forbid repetitive dives (also called successive dives). For example, section 10.1 of chapter 10 in the document IMCA D 022 says: *"The divers and standby diver all need to be medically fit to dive and clear of any decompression penalties"*. For this reason, diving companies affiliated with this organization or working for clients applying the guidelines of this organization apply this procedure. Thus, only one dive is organized passed the 12 or 18 hours the table used confirms the diver is cleared of decompression penalties.

2.2 - To conclude with this point

The procedures presented in the next chapter have been tested by military and sportive SCUBA divers and thought according to how sportive and occasional military diving operations are organized.

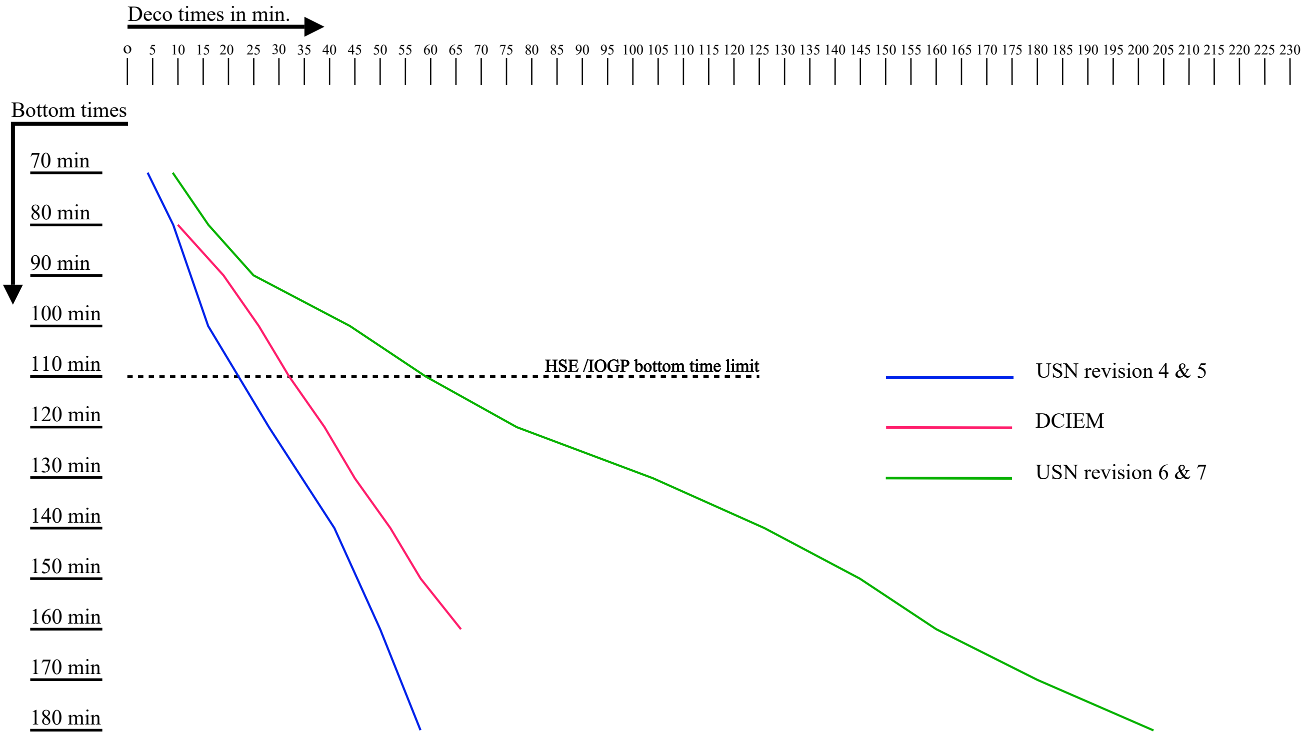
- Except for professional diving instructors, sports divers dive for pleasure. Thus, they are not required to perform daily dives.
- Based on the above, most sports divers have intervals between two dives of about one week (usually one dive/week) or more. Thus, they have the time to apply preconditioning solutions requiring preparation 24 hours before the dive.
- SCUBA divers decide when they start their dive. Thus, they can easily adapt to some procedures tested, such as performing pre-dive in water stops.

Opposite to sport diving, commercial diving operations involve substantial financial investments *(we speak of millions $)*, which recovery will depend on the success of the underwater operations carried on. As a result the diving supervisor is

required to optimize the dives he is in charge, and so, ensure that the divers and the equipment provided are employed adequately. Thus, teams are usually required to work within pre-established guidelines and scope of works where loss of time and unnecessary personnel are usually banished.
Despite these constrains and the fact that teams are often under pressure, it must be said that the frequency of decompression incidents has been widely diminished since the implementation of the decompression models currently used, and also the fact that numerous teams do not hesitate to apply the reinforcement procedures described above. However, these reinforcement procedures result in additional decompression times. In addition to these reinforcement procedures, we need to say that the trend of some teams updating or creating tables is to increase the duration of the decompression stops. It is, for example, the case of the latest revision of the US Navy tables that provide extremely long decompression stops for some depths. That can be seen in the extract below of a comparison of this table with the DCIEM procedures made by CCO Ltd *(In this study, "ascent time"= ascent rate + deco. Stops in minutes).*

Comparison ascent times USN 4, USN 5, USN 6, USN 7, and DCIEM for a dive at 60 ft (in minutes)

Bottom time	***Ascent time USN-4 & USN-5***	***Ascent time USN-6***	***Difference USN 5 & USN 6***	***Ascent time USN-7***	***Difference USN 6 & USN 7***	***Ascent time DCIEM***	***Difference USN & DCIEM***
70	4:00	9:00	+5 (Rev 6)	9:00	0		
80	9:00	16:00	+7 (Rev 6)	16:00	0	10:00	USN +6
90		25:00		25:00	0	19:00	USN +6
100	16:00	44:00	+28 (Rev 6)	44:00	0	26:00	USN +18
110		59:00		59:00	0	32:00	USN +27
120	28:00	77:00	+49 (Rev 6)	77:00	0	39:00	USN +38
UK-HSE bottom times limit							
130		104:00		104:00	0	45:00	USN +59
140	41:00	126:00	+85 (Rev 6)	126:00	0	52:00	USN +74
150		145:00		145:00	0	58:00	USN +87
160	50:00	160:00	+110 (rev 6)	160:00	0	66:00	USN +94
170		180:00		180:00	0		
180:00	58:00	203:00	+145 (Rev 6)	203:00	0	82:00	USN +121



Considering that DCIEM tables have similar decompression curves as COMEX MT 92 tables and that these two tables give excellent results *(MT 92 has been kept unchanged by the French ministry of labour in their latest revision published in 2019)*, we can question the reason for these long stops?

I believe the team that made this revision had his reasons; however, the ascent time for 120 min bottom time at 60 fsw is double that of DCIEM, so 77 minutes instead of 39 minutes.

Even though the procedures mentioned previously prove that commercial diving teams can minimize the problems posed by long decompression procedures, we can see that continuously increasing the decompression times may create organization issues and thus may not be a suitable solution for future algorithms. Such trends could be perhaps avoided if the pre-dive conditioning procedures discussed in the various documents taken into consideration in this study are efficient enough. Thus, in addition to reinforcing existing processes, this new concept may open the gate to other solutions than those commonly applied these last twenty years.

Based on these elements, in addition to the fact that they must reinforce the existing decompression strategies, we can say that ideal pre-dive conditioning procedures for commercial diving activities should be easy to implement, not impact the diving time, not affect too much the interval between two dives, and have been tested under scientific control.

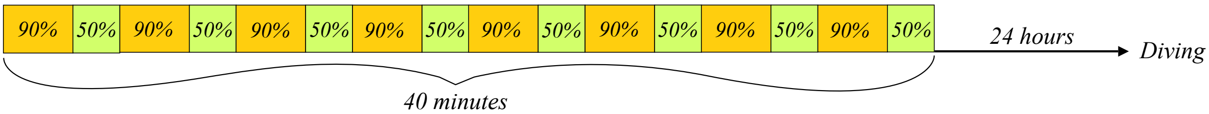
3 - Description of various experiments on pre-dive conditioning

3.1 - Endurance exercise

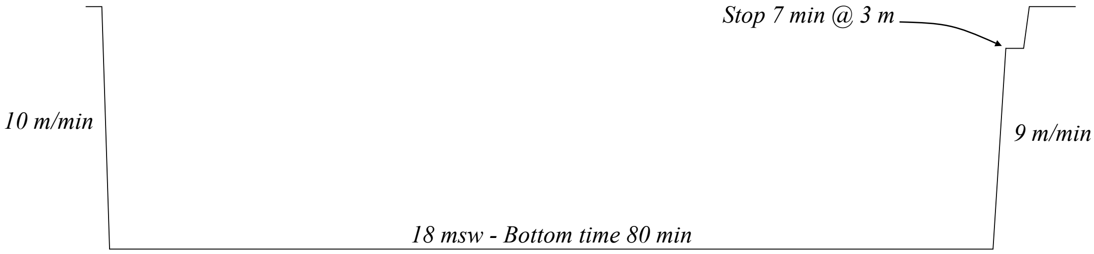
3.1.1 - Description:

Three studies can be taken as reference:

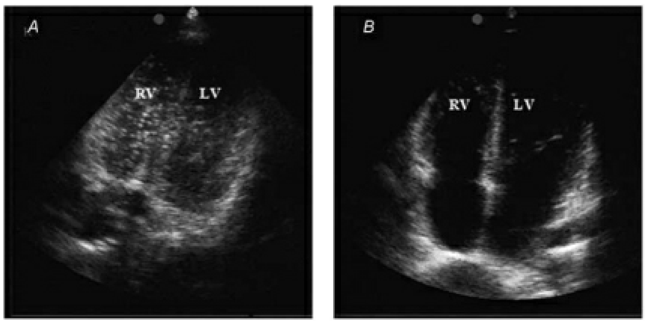
A. *"Aerobic exercise before diving reduces venous gas bubble formation in humans"*, is a paper published in 2004 by a scientists team composed of doctors Zeljko Dujic, Darko Duplancic, Ivana Marinovic-Terzic, Darija Bakovic, Vladimir Ivancev, Zoran Valic, Davor Eterovic, Nadan M Petri, Ulrik Wisløff, and Alf O. Brubakk. It describes pre-dive procedures consisting of submitting divers to, using a treadmill system, an exercise at 90% of maximum heart rate for 3 min, followed by exercise at 50% of maximum heart rate for 2 min, repeated eight times for a complete exercise period of 40 min, performed 24 hours before the dive.



The tested population was thirteen men aged 22–38 years in perfect physical condition (2 were smokers). The divers were compressed in a hyperbaric chamber to 280 kPa (18 msw) at a rate of 100 kPa min (10 m/min), breathing air and remaining at pressure for 80 min. They were then decompressed at a rate of 90 kPa min (9 m/min) to 130 kPa (3 msw), where they remained for 7 min before they were decompressed to the surface pressure (100 kPa) (1 bar) at the same rate (US Navy procedure -1996).
Each diver performed two dives 7 days apart, one with and one without physical exercise 24 h before the dive.



The monitoring was performed every 20 min for 80 min after reaching surface pressure (first measurement completed at 20 min after the dive).
The authors said the following to explain the aim of their experiment:
"Hills (1992) has demonstrated that the endothelium of veins and the aorta are hydrophobic due to a coating of surface-acting substances and that bubbles can be stable more of less indefinitely on a hydrophobic surface. Since it has been shown that NO is released from the endothelial cells following exercise (Buga et al. 1991) and that NO inhibits leucocytes and platelet adhesion and aggregation (Bult, 1996), it is conceivable that an increase in NO will also reduce the hydrophobicity of the endothelial wall, thereby reducing the number of nuclei. It has been demonstrated that NO can act both as a mediator for cell injury and as a cytoprotective agent. The mechanism for the preventive effect of a single bout of exercise on bubble formation may be linked to NO production (Wisløff et al. 2003)".
As a result of these experiments, the authors said that in this process, both maximum bubble grades and average bubble numbers were significantly reduced during the 80 min observation period, as it can be seen in the picture below.



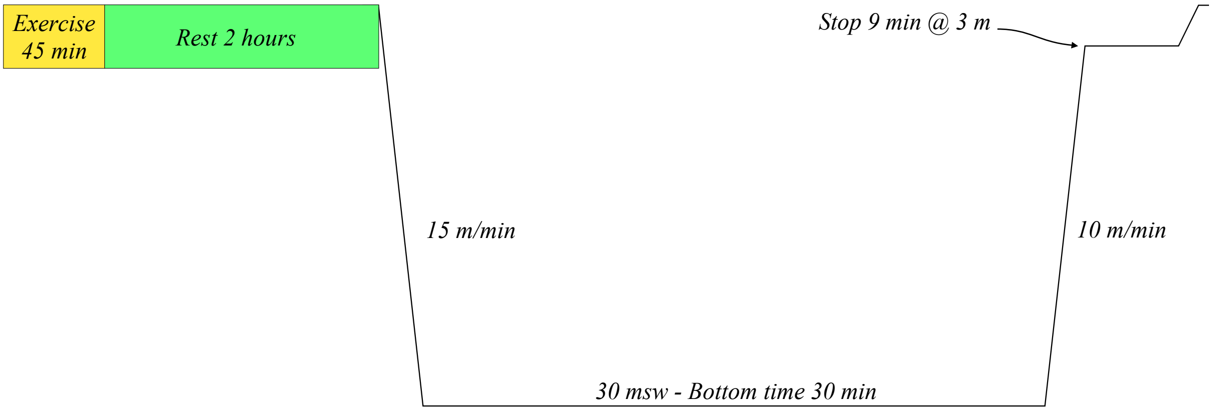
This figure depicts change in venous gas bubbles within the right heart and pulmonary artery following a dive without (A) and with (B) a previous bout of strenuous exercise in one diver:

- *In A, there are numerous, clearly visible venous gas bubbles.*
- *In B, after performing the exercise, bubbles are completely absent.*

The authors conclude that both the maximum number of bubbles and the total bubble load were reduced, so that a single bout of exercise 24 h before performing a dive significantly reduced the number of bubbles in the right heart of divers.

B. *"Aerobic exercise 2 hours before a dive to 30 msw decreases bubble formation after decompression"* is an article written in 2005 by Jean-Eric Blatteau, Emmanuel Gempp, Francois-Michel Galland, Jean-Michel Pontier, Jean-Marie Sainty, & Claude Robinet. It explains another process that consists of a single bout of an aerobic exercise 2 h before a dive, and concludes that they result in lower bubble scores in human volunteers following decompression. Sixteen trained military divers in perfect physical condition were involved in this study.
The procedure was that each volunteer performed sub-maximal exercise consisting of endurance running at an

intensity of 60 - 80% of maximum theoretical heart rate for 45 minutes. The divers were then compressed two hours later in a hyperbaric chamber to 30 msw (400 kPa) at a rate of 15 m/min, breathing air and remaining at rest at pressure for 30 min. They were decompressed at a rate of 10 m/min to 3 msw, where they remained for 9 min before they were decompressed to the surface at the same rate.

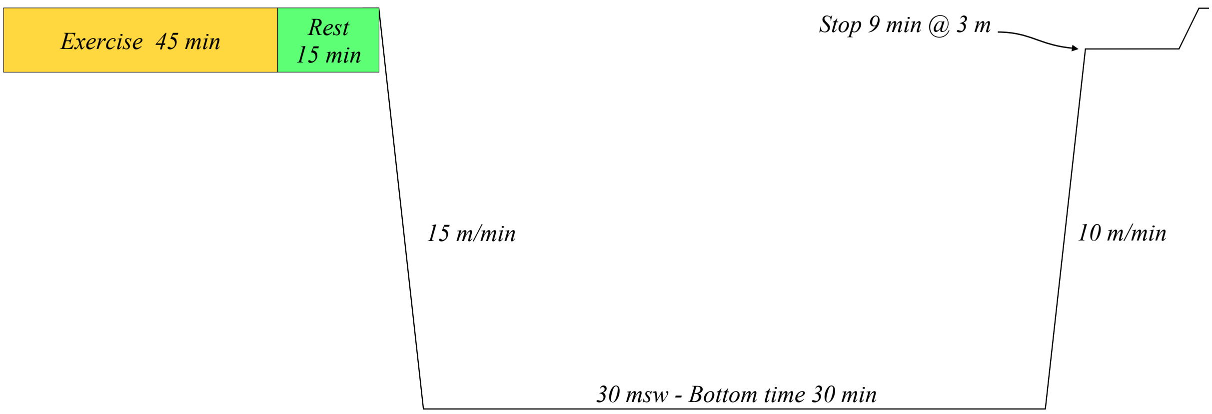


Bubble detection was carried out at 30 and 60 min after surfacing. The divers were supine for 3 min at rest, then two successive lower limb flexions were performed.
Venous Gas Embolisms (VGE) detection was performed with a pulsed doppler by an experienced operator.
Lower bubble scores were confirmed following the pre-dive conditioning process.

To explain this lower bubble score, the authors say that the likely mechanism by which aerobic exercise activates endothelial function is an increase in vascular shear stress resulting from increased blood flow.
This beneficial effect seems essentially related to an increase in vascular endothelial nitric oxide (NO) bioavailability (increasing production and/or decreasing NO inactivation). Aside from effects on vascular tone, it has been established that NO inhibits leukocyte and platelet adhesion under low and high shear conditions and could reduce hydrophobicity of the endothelial wall, reducing the number of nuclei adhering to the surface.
It is speculated that physical activity may trigger the synthesis of molecular species that are expressed in the endothelium about 20 h later, leading to an increase in endothelial NO synthase (eNOS) activity through activation of several signals transduction pathways.
They however, say that other studies suggest that other mechanisms may be associated and should be considered, and conclude this paper as follows: *"This study demonstrates that a single bout of aerobic exercise 2 h predive decreases venous gas bubble formation in man. These results could have considerable implications for DCS prevention. Further work is needed to elucidate the mechanisms underlying this exercise-induced reduction in bubble formation".*

C. *"Endurance exercise immediately before sea diving reduces bubble formation in scuba divers"* is another paper written by Olivier Castagna, Jeanick Brisswalter, Nicolas Vallee, and Jean-Eric Blatteau, and published in 2010

As suggested by the title, this experimentation consisted of immerging the volunteers 15 minutes after a single bout of sub-maximal exercise consisting of endurance running at an intensity of 60–80% of maximum theoretical heart rate (220 -age) for a total exercise session of 45 min. The volunteers were allowed to drink water freely during the 15 min between the end of exercise and the immersion.
Twenty-four healthy divers aged from 24 to 40 years were involved in this experiment.
The depth of each dive was set to 30 msw, and the bottom time was 30 min. The ascent rate was set at 10 m / min with a decompression stop at 3 m for 6 min. The divers breathed air, and did not performed strenuous exercise during the dive.



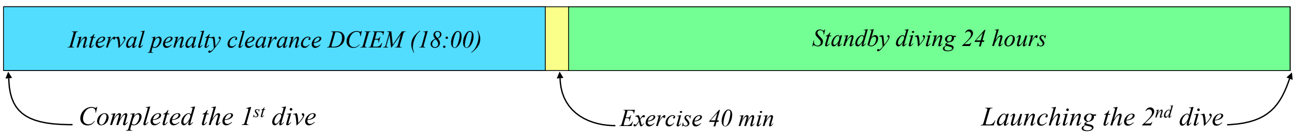
The authors explain that the main result of this study was a demonstration of the protective effect of a single bout of exercise taken immediately before a dive, expressed by a significant decrease in circulating bubbles assessed after a dive.
They also provide the following explanations:
"Previous studies have already observed the protective effect of exercise, but according to different authors, a delay of several hours was considered necessary between the end of exercise and the beginning of the dive

(Dujic and Duplancic 2004; Blatteau and Gempp 2005; Blatteau and Boussuges 2007; Dujic and Valic 2008). The novelty of this study is that it demonstrates that it is not necessary to wait for a certain period before diving after exercising.
This observation is particularly interesting for military divers, who, because of their military activity, cannot rest for many hours after exercising before diving.
Conversely, previous studies have shown that passive or active movement before compression acutely increased bubble formation. They suggested that exercise immediately before decompression could either increase the number of nuclei or increase their size, thus requiring less supersaturation to grow. However, most of these studies were performed in animals, using electrical muscle stimulation or by applying much higher levels of exercise intensity than were used in this study.
Furthermore, the only study performed on humans (Dervay and Powell 2002) took place under conditions of hypobaric exposure using an exercise protocol (knee-bend squats) which was quite different from the one used in this study (running, endurance effort).

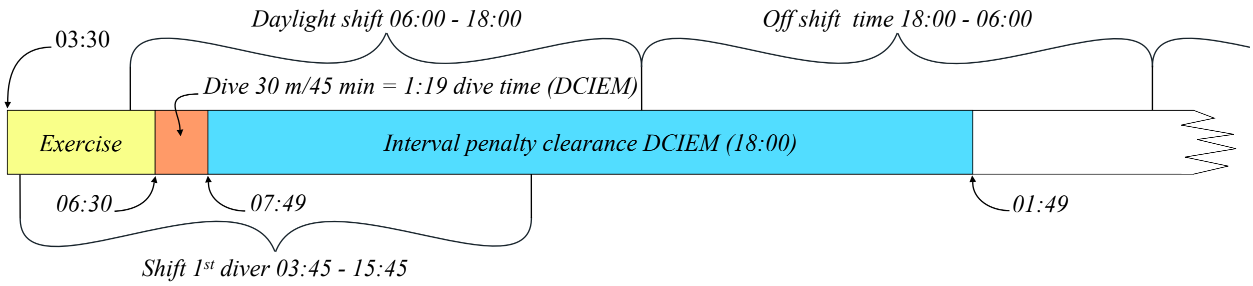
To conclude they say: This experimentation resulted in a significant decrease in circulating bubbles assessed after the dives. Another significant result of this study is to note that the reduction in venous gas emboli is correlated not only to the temperature rise, the volume of body fluid, and body mass decrement induced by this exercise but also to the volume of water drunk at the end of the exercise.

3.1.2 - Discussion

Of course, for the reasons mentioned before, some of the experiments mentioned are not applicable with the rules in force in the commercial diving industry.
For example, the solution of the procedure *"Aerobic exercise before diving reduces venous gas bubble formation in humans"* is not applicable for teams organized to dive every day because, depending on the table, the minimum surface interval to be fully cleared from decompression penalties ranks from 12 to 18 hours, and it is not recommended to perform efforts at a 90% heart rate during this period. As an example, the surface interval DCIEM to be fully clear for decompression penalty is 18 hours. Thus, if the diver starts his exercise session immediately when this surface interval is completed, he will finish this session at 18:40 after having completed the previous dive and will be able to dive only 42:40 hours later instead of 18 hours if the team applies the IMCA recommendation mentioned before regarding successive dives.



The solution described in the document *"Aerobic exercise 2 hours before a dive to 30 msw decreases bubble formation after decompression"* is more applicable. However, it would be uncomfortable for a team working alone and daylight only. Considering a team working 6:00 to 18:00 with the 1st dive launched immediately after the toolbox talk so at 6:30. In this case, 1st diver has to wake up around 3:30 to perform his predive exercise (if cleared of decompression penalty), and has to be off shift 12 hours later, so 15:45 considering he has to start his exercises at 3:45.



The solution used in the study *"Endurance exercise immediately before sea diving reduces bubble formation in scuba divers"* is the most comfortable to implement: The process starts 1 hour before diving which doesn't create any organizational problems. In their conclusion, the authors say: *"Although it has classically not been recommended, exercising before diving could be more secure for the decompression stage, no matter what the delay is between exercise and undersea exploration".*
Nevertheless, we need to note that the old assumption that efforts immediately before diving have adverse effects is linked to observations that resulted in this deduction. Doctors Olivier Castagna, Jeanick Brisswalter, Nicolas Vallee, and Jean-Eric Blatteau explain that the processes of the ex periments that led to this assumption were mainly done on animals using electrical stimulation or by applying much higher levels of exercise intensity than those that were used in the study discussed. So that the mechanisms leading to decompression sickness deducted from these previous experiments should be reconsidered. However, even though this study's quality cannot be doubted, based on the idea of the conservative approach discussed previously, we have to consider that more experiments could be necessary to confirm what they say and consequently review our current diving theories and standards.

In conclusion, we can see that some of these processes would be difficult to apply by commercial teams, and some results put in question some of our current practices. It is, however, the purpose of research to continuously reinvestigate established standards and beliefs.
For these reasons, I think it more suitable to consider these experiments altogether, instead of focusing on only one or the

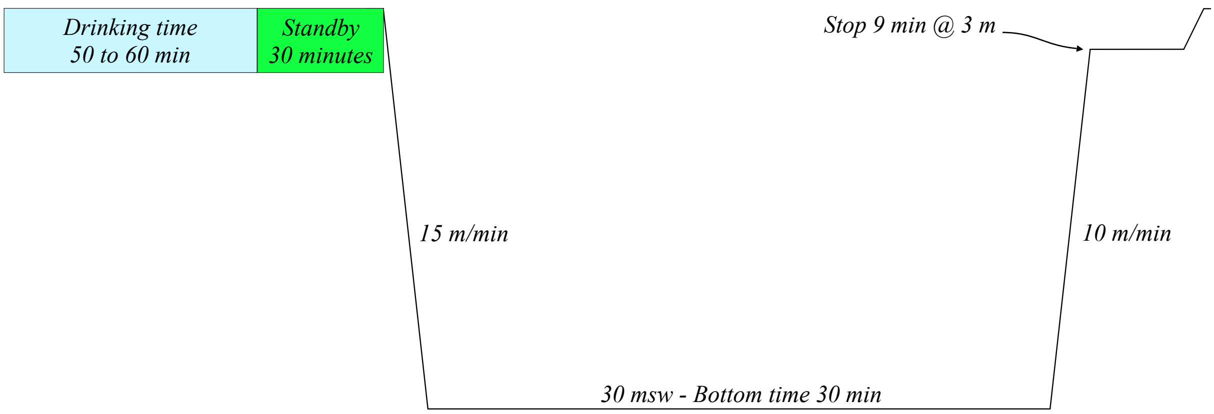
way they have been organized, as we need to keep their experimental side in mind.
Because all these procedures gave positive results, we can consider that a daily exercise of 40 - 45 minutes has positive effects on decompression, whatever the period of the day it is undertaken, which is in accord with the conclusion of Olivier Castagna, Janick Brisswalter, Nicolas Vallee, and Jean-Eric Blatteau in the study *"Endurance exercise immediately before sea diving reduces bubble formation in scuba divers"*. Also, these procedures confirm the conclusions of the adverse effects of bed rest mentioned by Jean-Pierre Imbert, Salih Murat Egi, Peter Germonpré, and Costantino Balestra regarding the studies from Gennser and Al. Thus, we can say that the daily physical training of divers should be institutionalized.
It must be noted that, if organized with a certain flexibility, this practice has no impact on the organization of the work as the divers can arrange these training sessions on their own during some available periods of their shift or their off-shift time when they are confirmed being outside any decompression penalty.
In addition to their positive effects on decompression, daily physical training increases or at least maintain body endurance, which is essential for these activities.
Treadmill systems were used for some of these experiments and are the only system that allows running at 60 - 80% of maximum heart rate on a boat. They are available today on many vessels, and using them should not create a problem of availability with a reduced diving team. However, additional units may be necessary if numerous divers are involved in the diving project.

3.2 - Hydration & heat exposure

3.2.1 - Description

Only one study of each concept has been found these two studies are grouped because they are the only pre-dive conditioning studies made on humans using the procedures mentioned. Also, even though they resulted in a significant reduction of VGE, they seem to trigger opposite mechanisms, which , as suggested by their authors, should be more investigated.

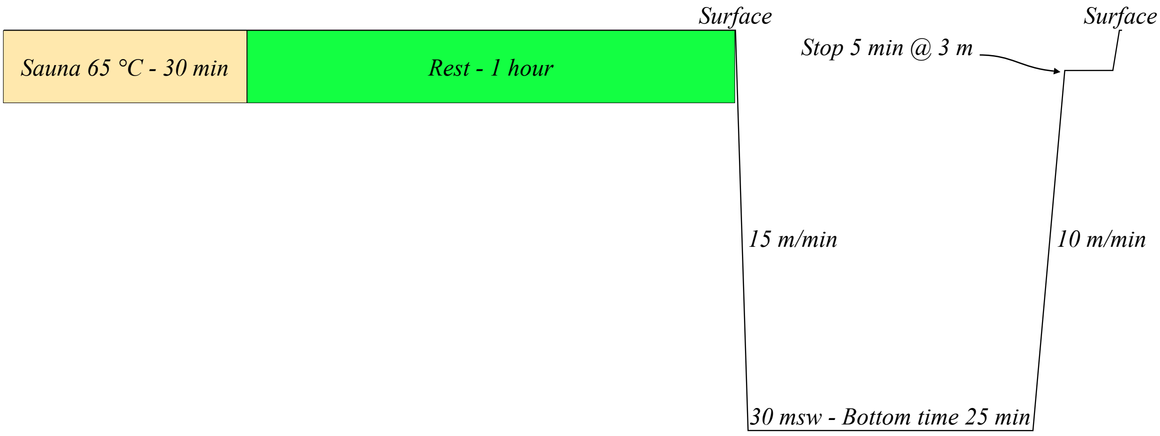
A. *"Preventive effect of pre-dive hydration on bubble formation in divers"*, published in 2008 by doctors E Gempp, J E Blatteau, J-M Pontier, C Balestra, & P Louge, seems the only study that can be considered a pre-dive conditioning procedure tested on humans.
   Its purpose was to investigate whether pre-hydration before a dive could decrease bubble formation and to evaluate the adjustments in plasma volume, water balance, and plasma surface tension resulting from these experimentations. Note that several studies regarding this topic have been made on animals.
   Eight healthy military divers were involved in this experiment. They were organized in two teams and performed in-water air dives at 30 msw for 30 min followed by a 9 min stop at 3 msw.
   - The divers involved with test dives had a pre-dive hydration of 1300 ml of saline–glucose beverage. This hydration started 90 minutes before the dive with a drinking time limited to 50 - 60 minutes.
   - The divers involved with the control dives had no pre-hydration.



   Saline–glucose beverage was used because it has been demonstrated that water alone is relatively ineffective for controlling and maintaining plasma volume.
   The authors say that this study supports the idea that pre-dive oral hydration of 1300 ml of a hyperosmotic fluid decreases circulatory VGE, thus offering a relatively easy means of reducing DCS risk. The pre-hydration condition allowed attenuation of the dehydration resulting from higher fluid retention and prevention of hypovolemia** induced by the diving session. They also say that, conversely, hydration did not appear to increase plasma surface tension in this study and consequently may have less influence on the risk of DCS than was previously thought. They conclude that further investigations are required to elucidate the mechanisms underlying this pre-hydration-induced reduction in bubble formation.
   (** Hypovolemia is a state of abnormally low extra-cellular fluid in the body.)

B. *"Predive Sauna and Venous Gas Bubbles Upon Decompression from 400 kPa"* is a study published by doctors Jean- Éric Blatteau, Emmanuel Gempp, Costantino Balestra, Tony Mets, & Peter Germonpre, which aim was to investigate the influence of a far infrared-ray dry sauna-induced heat exposure before a simulated dive on bubble formation, and examined the concomitant adjustments in hemodynamic parameters. The sessions were organized as follows:

- Sixteen trained military divers of 38.4 years average age (28 – 59 years) had a 30 min session at 65°C in an infrared-ray dry sauna system with the head out of the cabin.
- The sauna session ended 1 h before the dive. The divers were not allowed to drink water during the protocol.
- The divers were then compressed in a Deck Decompression Chamber (DDC) to 400 kPa (30 msw) at a rate of 150 kPa /min (15 m/min) for a bottom time of 25 min. No activities were performed during the bottom time.
- They were decompressed at a rate of 100 kPa/min (10 m/min) with a 4-min stop at 130 kPa (3 msw).



This study leaned on previous studies where the authors showed that moderate dehydration resulting in stroke volume reduction induced by a predive exercise could decrease venous circulating bubbles in divers. It is, for example, the case with the study "Haemodynamic changes induced by submaximal exercise before a dive and its consequences on bubble formation". Based on the results from these studies, the authors looked for a convenient means to obtain a state of moderate dehydration before diving. Thus, the selection of a sauna is based on the fact that it is recognized that high environmental temperatures lead to sweat response, resulting in dehydration.
A Doppler was used to detect bubbles 20, 40, and 60 min after surfacing, at rest, and after flexions. Brachial artery flow mediated dilation (FMD), blood pressure, and bodyweight measurements were taken before and after the sauna session along with the analysis of blood samples.

The authors say that the overall distribution of bubbles was not modified and that the maximum bubble count was observed 40 min after surfacing. They also say that the sauna session significantly reduced bubble grades at rest and after two lower limbs flexions except for one diver who showed a slight increase in venous bubble grade after the sauna treatment. Also, they were able to confirm an increase in flow mediated dilation, suggesting a NO-mediated effect on endothelial function after a single sauna session.
Their final conclusion is that this procedure could offer a new way of reducing decompression sickness risk. However, they also say that further investigation is required to elucidate the preponderant mechanism underlying this heat exposure-induced reduction in the bubble formation.

3.2.2 - Discussion

Regarding pre-dive hydration:

It has long been suggested that dehydration may increase the risk of Decompression Sickness (DCS), and several experiments have been made on animals that correlate this fact. It is, for example, the case of the study *"Dehydration Effects on the Risk of Severe Decompression Sickness in a Swine Model"* published In 2006 by doctors Andreas Fahlman and David M. Dromsky. However, the exact quantity of water provided to the animals is not documented. And because the experiment was made on animals with extreme compression and decompression profiles, it cannot be considered a pre-dive conditioning solution.
The study *"Preventive effect of pre-dive hydration on bubble formation in divers"* explains that the pre-dive oral hydration consisted to 1300 ml of a hyperosmotic fluid for dives without efforts.
As indicated by the authors in the presentation of this paper, pre-hydration of divers has been institutionalized for diving and marine teams working on vessels' decks in tropical areas, which results that saline-glucose beverages are usually available at all times, and people are taught to monitor their hydration through urine colour. Thus, surface-supplied divers pre-hydrate before starting their dive, and our current standards mention that it has to be done. In addition, it is today considered standard practice to pre-hydrate the divers in saturation before starting their bell run and to re-hydrate them at the mid-time of their dive time. Note that many saturation divers also carry portable bottles with a PVC straw inserted near the mouth through the neck dam of the helmet to drink as necessary during the long dives they are involved in.
Thus, considering what is said above and that the conclusion of this study seems to confirm it, we can deduce that hydration before and during the dive should be regarded as a safe practice unless new research proves the opposite.
That is confirmed by the conclusion of doctors Gempp & Blatteau in their article *"Preconditioning Methods and Mechanisms for Preventing the Risk of Decompression Sickness in Scuba Divers: A Review",* published in 2018, where they say that evidence suggests that, for a population of trained and military divers, endurance exercise (even in a warm environment) associated with oral hydration prior to the dive is beneficial in vascular bubble reduction.

Regarding heat exposure:

Of course, one problem with the procedure would be finding and installing an infrared-ray dry sauna system on the work site and make understood to some people that it is not a joke.
However, apart from this anecdotic point, the main issue to consider is that the results conflict with what we have been taught regarding the adverse effects of dehydration on decompression. That should not be a problem if the study "Preventive effect of pre-dive hydration on bubble formation in divers" discussed above demonstrated that pre-dive hydration triggers adverse effects. Still, the authors confirm that it is the opposite and even recommend hydration (refer to what doctors Gempp & Blatteau conclude regarding this point). Thus, we have two methods that improve bubble count after diving with the diver status in apparently opposite conditions.
The authors say that further investigations are needed to understand the mechanisms linked to a reduction in bubble formation using this procedure. Nevertheless, I have not found a paper regarding the continuation of this investigation, which makes me like a dog observing a bone it cannot reach! For these reasons, using a sauna should not be regarded as a predive conditioning procedure currently applicable by diving teams but as a method of investigation that should be reproduced under strict scientific monitoring.

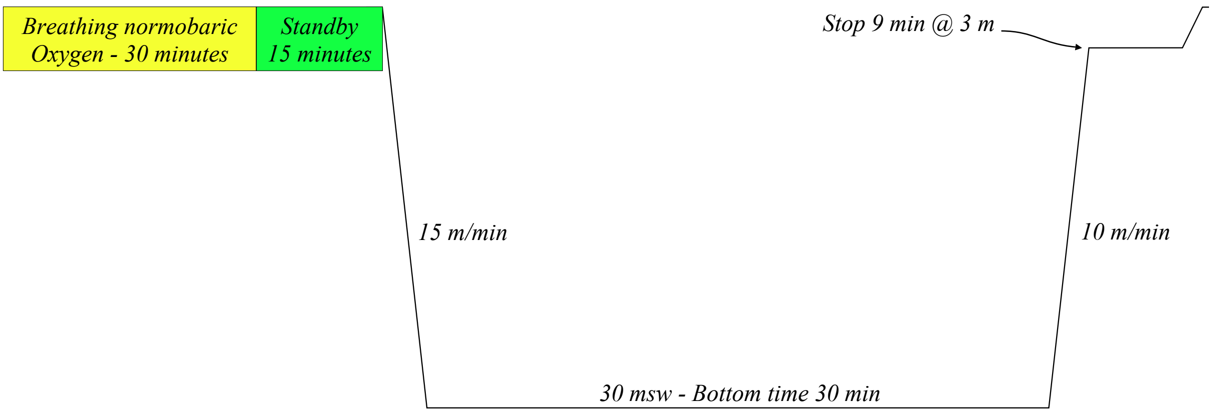
3.3 - Oxygenation

3.3.1 - Description

Three papers are described in this section. One explains experiments with normobaric oxygen, and the two other describe experiments made with hyperbaric oxygen.

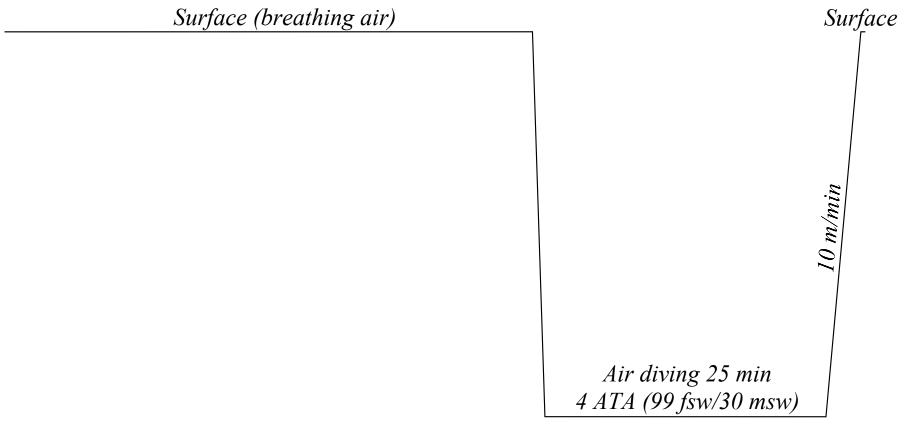
A. *"Pre-dive normobaric oxygen reduces bubble formation in scuba divers"* is a study made in 2009 by doctors Olivier Castagna, Emmanuel Gempp, & Jean-Eric Blatteau to evaluate the effect of 30-min normobaric oxygen breathing before diving upon bubble formation in divers.
Repetitive open-sea dives under four experimental conditions in counterbalanced order were organized.
    - A dive without oxygen pre-breathing and a successive dive without oxygen pre-breathing (air - air).
    - A dive with oxygen pre-breathing and a successive dive with oxygen pre-breathing (O2 – O2).
    - A dive with oxygen pre-breathing and a successive dive without oxygen pre-breathing (O2 - air).
    - A dive with without oxygen pre-breathing and a successive dive with oxygen pre-breathing (air – O2).

    The divers tested consisted of 8 women and 13 men 23 to 41 years old in perfect physical condition.
    Pre-dive oxygenation was performed during 30 minutes through a breathing mask.
    The dive profile of the 1st dive was 30 msw for 30 min followed by a 9 min stop at 3 msw. The successive dive had the same profile after a surface interval of 2 hours

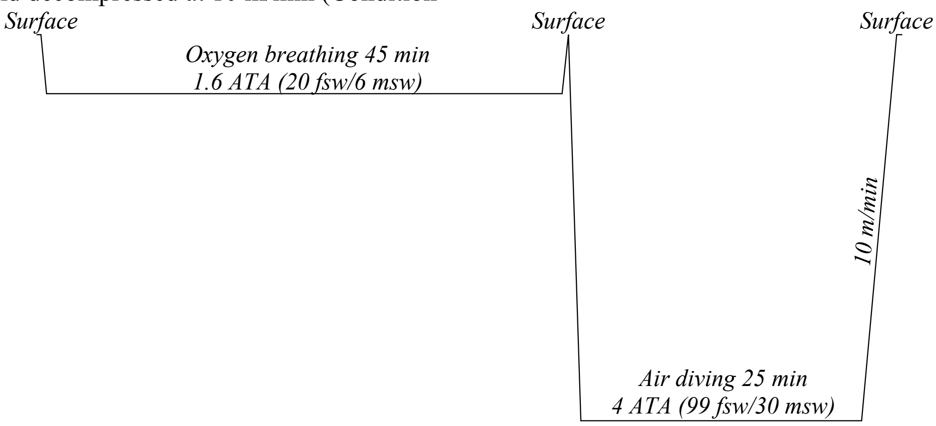


    As a result of these experiments, when the two dives were performed with pre-dive oxygen breathing (O2 – O2), the bubble score after the successive dive was significantly lower than that measured in the two situations where only one of the two dives was performed with pre dive oxygen breathing (O2 – air) & (air – O2).
    Note that when oxygen is breathed before only one of the two dives, the bubble score of the successive dive is always lower than a condition where oxygen is not breathed before the 1st and the 2nd dive (air - air).
    As a conclusion, the authors of this study say that this study demonstrates that 30 min-normobaric oxygen pre-breathing ending 15 min prior to diving decreases VGE, and that this procedure could provide protection from DCS, particularly in multi-day repetitive diving. They also say that studying the mechanisms involved in reducing gas nuclei population by oxygen warrants further experiments.

B. *"Pre-treatment with hyperbaric oxygenation reduces bubble formation and platelet activation"* is a study made by doctors A. Landolfi, Z.J. Yang, F. Savini, E.M. Camporesi, F. & Faralli, G. Bosco, and published in 2006.
Its purpose was to correlate the hypothesis that pretreatment with hyperbaric oxygen immediately before a dive may reduce bubble formation and platelet activation in humans, and so, the risks of decompression sickness.
The population of divers involved comprised four men and one woman of 33.6 years average age.
Dives were simulated according to two conditions of compression and decompression:
    - On day 1, subjects were compressed at 4 atmosphere absolute (ATA) for 25 minutes and then decompressed at a rate of 10 m/min (Condition A).



- The day after, subjects were compressed at 1.6 ATA for 45 min with 100% oxygen (hyperbaric oxygenation) and then decompressed to surface pressure at a rate of 10 m/min (always breathing oxygen); as soon as surface pressure was reached, they were immediately recompressed at 4 ATA for 25 minutes and decompressed at 10 m/min (Condition



- After three months, on day 3 and 4, simulated diving was carried out according to Condition B and then Condition A, respectively, to minimize the influence of immersion on bubble formation.

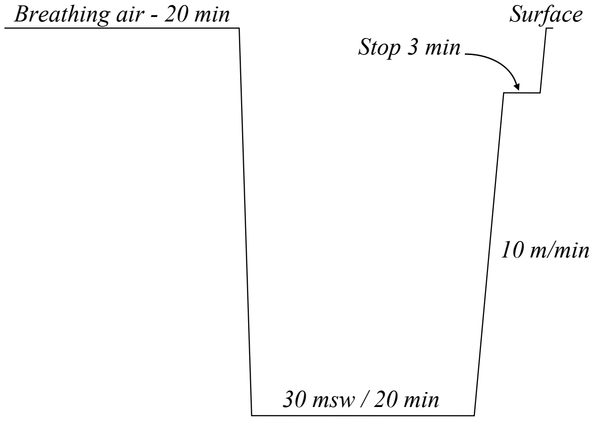
The result of the study was that pre-treatment with hyperbaric oxygen significantly reduced the bubble grade detected by Doppler at 20 min. Thereafter, the bubble grade greatly decreased either at 50 or at 80 min, showing no significant difference between the two groups.
There was no difference in Doppler signals between those measured at rest and after movement.
Pretreatment with hyperbaric oxygen (Condition B) significantly attenuated platelet activation compared to Condition A.

To conclude, the authors say that pretreatment with hyperbaric oxygen (1.6 ATA for 45 min with 100% oxygen) immediately before diving significantly reduced decompression-induced bubble formation and platelet activation. So, that pretreatment with hyperbaric oxygen may be beneficial in reducing the risk of decompression sickness.

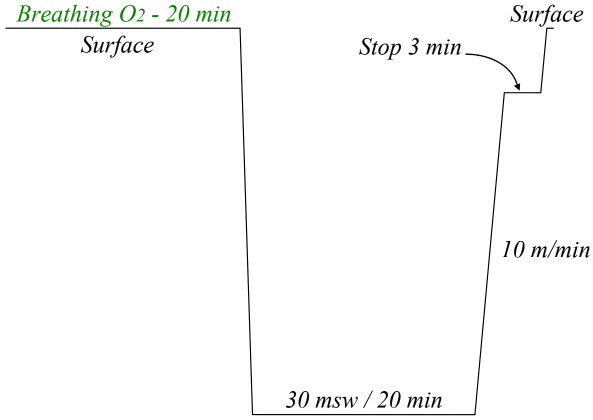
C. *"Effect of in-water oxygen prebreathing at different depths on decompression-induced bubble formation and platelet activation"* is a study published in 2007 by doctors Gerardo Bosco, Zhong-jin Yang, Guglielmo Di Tano, Enrico M. Camporesi, Fabio Faralli, Fabio Savini, Angelo Landolfi, Christian Doria, and Giorgio Fanò.

This document compares pre-dive conditioning using normobaric oxygen breathing with predive conditioning using hyperbaric oxygen breathing at 6 m or 12 m. Several dives at 30 msw (4 ATA) with 20 min bottom time, an ascent rate of 10 m/min, and a 3 min decompression stop at 5 m were organized for this purpose.

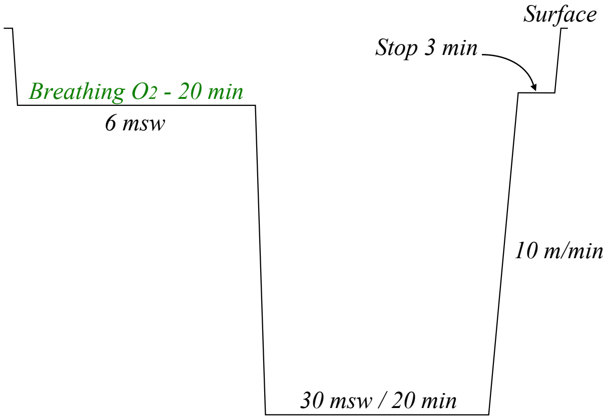
- Dive 1: The divers breathed air for 20 min at the surface (Air) before starting the dive.



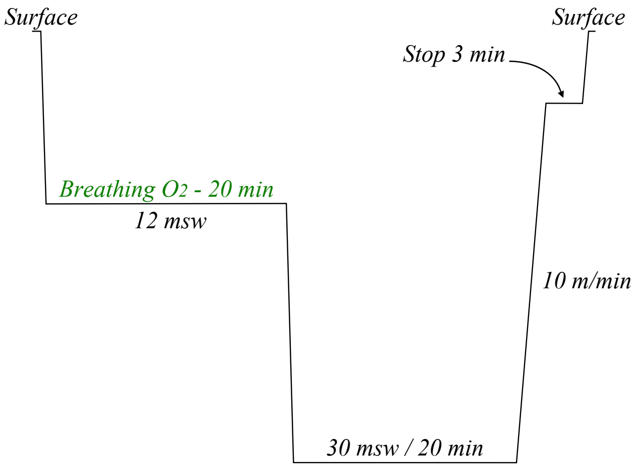
- Dive 2: The divers breathed 100% oxygen for 20 min at the surface (NBO) before starting the dive.



- Dive 3: The divers breathed 100% oxygen for 20 min while submerged at 6 msw (HBO 1.6 ATA) before starting the dive.



- Dive 4: The divers breathed 100% oxygen for 20 min while submerged at 12 msw (HBO 2.2 ATA) before starting the dive.



The authors of this study give the following conclusions:

- Prebreathing Normobaric Breathing Oxygen (NBO) for 20 min immediately before an open seawater dive while breathing air significantly reduced decompression-induced bubbles detected at 20 min postdive, but not at 50 min.
- Prebreathing Hyperbaric Breathing Oxygen (HBO) significantly reduced detected air bubbles at 20 and 50 min postdive.
- Prebreathing HBO more effectively reduced decompression-induced air bubbles than prebreathing NBO.
- Prebreathing HBO more effectively alleviated decompression-induced platelet activation than prebreathing NBO.

3.3.2 - Discussion

To explain the results observed, the authors say that the proposed mechanism involved in pre-dive conditioning is the ability of oxygen to replace nitrogen in the gas nuclei by diffusion. The reduction of the oxygen pressure after switching from oxygen to air could enhance oxygen consumption from the nucleus, thus eliminating it completely. This new concept is different from the one taught to us that a rise in arterial oxygen pressure when breathing pure oxygen encourages the diffusion of dissolved inert gas from tissues into the blood. Consequently, the resolution of resident inert

gas is accelerated, tissue nitrogen super-saturation during decompression is reduced, and thus bubble generation is limited.
As already said, these studies have been organized to validate scientific assumptions and not establish new procedures applicable for industrial diving activities.

The normobaric pre-dive oxygen breathing described in the paper, "Pre-dive normobaric oxygen reduces bubble formation in scuba divers", is easy to implement, so it can be considered a valid pre-dive conditioning process for dives using standard air.
However, because no tests have been made with nitrox** and oxygen decompression stops, we must abstain from merging this concept with these procedures, even though there is no apparent conflict, and we feel that the two concepts used together may give excellent results. That is, of course, based on the conservative approach discussed previously. Thus that, only procedures that have been tested and validated should be used.
(** Nitrox: In diving activities, it is a mix oxygen/nitrogen where the PPO2 is above 21%)

The two other procedures would be challenging to apply by a team working applying to the rules currently in force in the diving industry for reasons such as the following:

- Applying such procedures would result in the obligation to assign a team to monitor the diver during the oxygen stop and provide additional equipment if the pre-dive conditioning is performed in parallel.
- Organizing continuous diving with such procedures would result in conflicts regarding the availability of the monitoring team and the additional equipment, with some bottom times. That would result in another team being involved with the appropriate equipment.
- Launching a dive that begins with 45 or 20 minutes stop time, where the diver does nothing, is difficult to justify to clients when decompression stops are also to be done at the end of the bottom time. In addition, the current rule in force is that a dive starts when the diver has the airways 1 m below the surface. Thus, to be legally applicable, such a procedure would have to be recognized by an official body and accepted by the country's authorities.

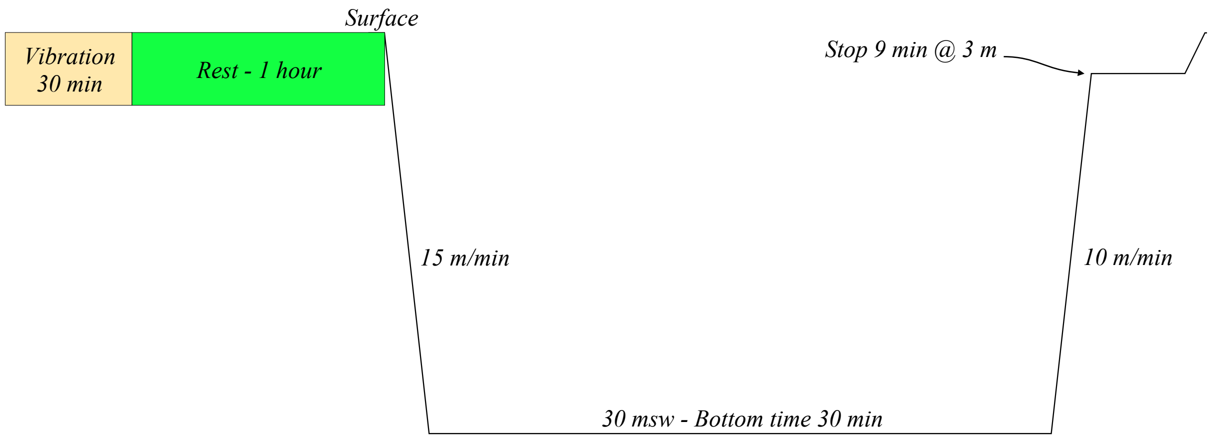
Like some concepts already discussed, the hyperbaric predive oxygenation methods presented should not be regarded as procedures currently applicable but as experiments that, on the one hand, give us a new approach regarding the comprehension of the mechanisms triggered by oxygen breathing and pose us many unanswered questions on these phenomenons on the other hand.

3.4 - Pre-dive vibration & jumping

3.4.1 - Description

Two pre-dive conditioning by vibration studies have been found; one of the two compares the efficiency of predive vibration with oxygen. Only one study on the use of jumping has been found. It is based on the use of mini trampolines. The reason is that this concept is new and was revealed at the beginning of this year only. As a result, this study is grouped in the same section because it aimed to trigger similar effects to vibration and has been made by some members of the teams involved in pre-dive conditioning by vibration.

A. *"Pre-Dive Vibration Effect on Bubble Formation After a 30-m Dive Requiring a Decompression Stop"* is a study published in 2009 by Peter Germonpré, Jean-michel Pontier, Emmanuel Gempp, Jean-Eric Blatteau, Stefaan Deneweth, Pierre Lafère, Alessandro Marroni, and Costantino Balestra, that discusses a procedure consisting to precede the dives by a whole body vibration session of 30 minutes using a commercially available vibration mattress vibrating at frequencies from 35 to 40 Hz. The volunteer laid motionless on the mattress during the entire vibration session, which ended 1 h before the start of the dive.
The choice of vibration frequency (35-40 Hz) and duration (30 min, ending 1 h before the dive) was arbitrary and based on practical considerations
The dives were made in open (sea) water, and consisted to a depth of 30 m, and 30 min bottom time with calibrated effort during the dive (fin swimming at a determined leg frequency and speed). A 9 minutes decompression stop was made at a depth of 3 msw.



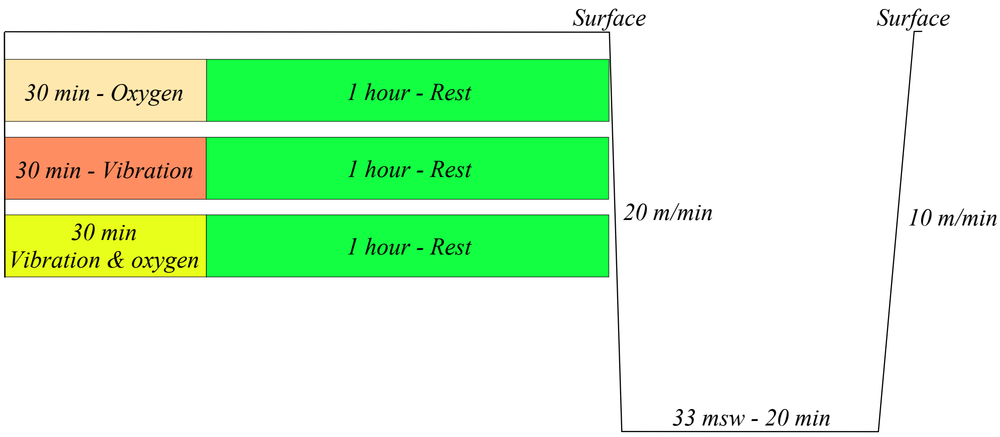
Fourteen healthy male military divers, approximately 29 years old, were involved in this experiment, and doppler measurements were made at 30, 60, and 90 min after the dive, both at rest and after knee flexions.

The authors say that reduction in Vascular Gas Embolisms (VGE) after a "vibration" dive failed to reach significance at rest but was significant after knee flexion. As an explanation, by increasing the shear stress on the vessel wall, the knee flexion maneuver increases the liberation of any existing, adherent gas bubbles. Therefore, the amount of VGE observed after knee flexion reflects more accurately the number of gas bubbles actually present than the values at rest.
They also say that the results suggest that the sources of potential post-dive gas bubbles (i.e., vessel wall gas nuclei) have been widely reduced due to pre-dive vibration.
In the document *"Preconditioning to Reduce Decompression Stress in Scuba Divers",* published in 2018, doctors Peter Germonpré & Costantino Balestra say that vibration and sauna might act by mechanical dislodging of VGE nuclei (either by the transmission of energy shocks or by increased shear forces with increased circulation). Also, both factors might be involved in the effects seen in pre-dive exercise preconditioning, as this provokes an increased cardiac output and mechanical movement.

B. *"Pre-dive Whole-Body Vibration Better Reduces Decompression-Induced Vascular Gas Emboli than Oxygenation or a Combination of Both"*, is a paper published in 2016 by doctors Costantino Balestra, Sigrid Theunissen, Virginie Papadopoulou, Cedric Le Mener, Peter Germonpré, François Guerrero, & Pierre Lafère.

The purpose of this study was compare oxygen and vibration predive solutions and whether a combination of the two is beneficial. Several test dives were organized for this purpose.

- Six divers performed 6 no-decompression dives each, to a depth of 33 msw for 20 min.
  - 3 control dives without preconditioning
  - 1 dive with oxygen preconditioning using 100% normobaric oxygen (O2) breathed through a mask.
  - 1 dive with a whole-body vibration session (Vib) preconditioning using a commercially available vibration mattress (Vibration frequencies ranged from 35 to 40 Hz)
  - 1 dive with oxygen + vibration preconditioning (VibO2) performed simultaneously.
- The descent rate was 20 m/min and the ascent rate was 10 m/min. The divers were asked to swim slowly without effort during the bottom time
- There was a minimum interval of 1 week between each dive.
- The post-dive bubble count was performed in the precordium by two-dimensional echocardiography, 30 and 90 min after the dive, with and without knee flexing.
- The divers laid motionless on the mattress during the entire vibration session, or a non-vibrating mattress while only breathing oxygen.
- The duration of preconditioning sessions was 30 min. They were organized to end 1 h before the start of the dive.

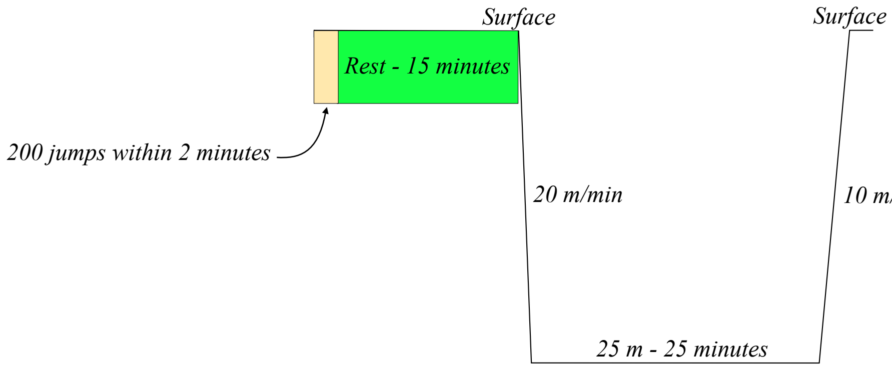


This study was based on the fact that experiments with pre-dive breathing of normobaric oxygen or pre-dive body vibration significantly reduced the amount of bubbles after the dive.
The results showed that pre-dive conditioning by body vibration was more efficient than predive-conditioning with normobaric oxygen and pre-dive conditioning with vibration + normobaric oxygen.
However pre-dive conditioning with vibration + normobaric oxygen gave better scores than normobaric oxygen. The authors conclude these results by saying it is reasonable to assume a synergistic effect of oxygen and vibration, but it is the opposite that was observed. They also say that this absence of synergy could be explained by the fact that the two modes of preconditioning, mechanical or diffusion, could act on the same nuclei and thus be in direct competition. Based on these findings, doctors Jean-Pierre Imbert, Salih Murat Egi, Peter Germonpré, and Costantino Balestra say : *"The best pre-conditioning sequence would be to, at first, expose the diver to vibrations to reduce the Static Metabolic Bubbles (SMB) density and then reduce the volume of the remaining SMB by oxygen breathing. However, this remains to be experimentally tested"* **.
(** See in the study: "Static Metabolic Bubbles as Precursors of Vascular Gas Emboli During Divers' Decompression: A Hypothesis Explaining Bubbling Variability")

C. *"Mini Trampoline, a New and Promising Way of SCUBA Diving Preconditioning to Reduce Vascular Gas Emboli?", is a* study published in April 2022 by doctors Kate Lambrechts, Peter Germonpré, Joaquim Vandenheede, Manon Delorme, Pierre Lafère, and Costantino Balestra, aimed to test the use of a mini trampoline (MT) as a preconditioning strategy based on jumping. Doctors Peter Germonpré, Pierre Lafère, & Costantino Balestra were previously involved in experiments with whole body vibration. Thus, this study can be regarded as the continuation of these experiments.

This study aimed to verify the hypothesis that the combination of mechanical and cardiovascular activations (even of short duration) can reduce gas nuclei elimination before diving, with a concomitant reduction in post-dive Vascular Gas Emboli (VGE). Therefore, both stimuli (mechanical and cardiovascular) were coupled using the mini trampoline device, which is a cheap and accessible method, even in confined environments such as boats. Finally, as already seen with sauna preconditioning, they also hypothesized a positive effect on endothelial function, which should be preserved and not reduced as usually seen after diving, particularly when using a normal diving mask, which was the case in their setting.

- Eight (5 females and 3 males) healthy, non-smoking, experienced SCUBA divers with an average age 36 of years (± 16 years) were recruited for this study. They were instructed to abstain from any physical activity and diving for 72 h prior to the experimental protocol. Beverages with caffeine and alcohol were strictly prohibited for 6 h prior to the test.
- Each diver performed, in a random order, two standardized dives with and without preconditioning. The dives without pre-conditioning, called “control” by the authors, were used as references to evaluate the benefits of the “pre-conditioning “ procedure. The minimum interval between two dives was 1 week.
- The preconditioning strategy consisted of a 2 min bout of mini trampoline jumping, every diver was asked to perform at least 200 jumps, 15 min before the start of the dive.
- The test air dives were organized in a swimming pool with water temperature between 29 and 33 C. The profile selected was 25 minutes at 25 metres with no decompression stop. The descent speed was 20 m/min and the ascent rate was 10 m/min. No effort was required to the diver while arrived at depth apart swimming slowly.



- Bubble analysis were performed using a two-dimensional echocardiography technique 30 and 60 minutes after surfacing. The measurements were taken at rest (without flexion) and following two deep knee bends (with flexions).
- Ultrasound assessments were performed 20 -30 min after surfacing while participants rested in the supine position for at least 15 min to check the brachial artery Flow Mediated Dilation (FMD), and thus measure the endothelium-dependent vasodilation mediated by nitric oxide (NO).
- Statistical tests were performed using a standard computer statistical package.

As a result of these experiments, the authors say that compared to the “control”, VGE count was significantly reduced after trampoline preconditioning. However, they also say that no significant difference was found between the measurements at 30 and 60 minutes.
The authors also say that mini trampoline reconditioning prevented post-dive FMD decrease compared to the pre-dive values, while measurements exhibited a significant decrease in the absence of preconditioning, which conforms with previously reported data in the literature.

3.4.2 - Discussion

The fact that whole-body vibration results better than normobaric oxygen breathing and oxygen breathing + body vibration demonstrates that procedures that have not been scientifically tested must not be implemented, so the idea of the conservative approach must always prevail, even though we have the feeling that a procedure should work. For this reason, because this concept has not been tested with nitrox diving and oxygen stops, whole body vibration pre-dive conditioning should be implemented for standard air diving only.

The authors of the study on the use of mini trampoline say that it is interesting to note that mini trampoline preconditioning is associated with a reduction of 80.4% in VGE production and that FMD impairment is prevented (+10.4% compared to control dive). Therefore, they conclude that:

- The magnitude of the change in FMD is similar to a sauna, which induced comparable results of 10.9% FMD post-dive.
- VGE production is similar to whole-body vibration preconditioning which induced a reduction of 84% in post-dive VGE.

Based on these results, the authors say that mini trampoline can be considered a mixed preconditioning strategy that

allows the addition of two major actions.
In addition, although the vibration-like effect is far from obvious, a mechanical action cannot be denied. Jumping is associated with blood mass displacement (inertia), causing shear stress, while significant muscular contractions and contraction-related 'squeezing' of muscular and perimuscular vessels participate in the mechanical dislodging of VGE nuclei.
Finally, as seen in sauna preconditioning, effort-related compensations associated with jumping on the mini trampoline will activate cardiovascular compensations and putatively heat production. Due to the shorter exposition time, dehydration is probably less likely to participate in this simple method's effectiveness.

The authors also highlight that although dive profiles were very close and comparable, the mini trampoline session was ten times shorter, roughly 2 minutes, to reach the same benefit as vibration sessions that were 30 minutes long, so significantly most prolonged. In addition, this equipment is cheaper and easier to carry.
Although it can be believed that this procedure should provide similar benefits when used with nitrox diving and oxygen decompression, we cannot give any information on this for the reasons already explained. It would be urgent to verify this assumption.

3.5 - Pre-dive specific substances uptake

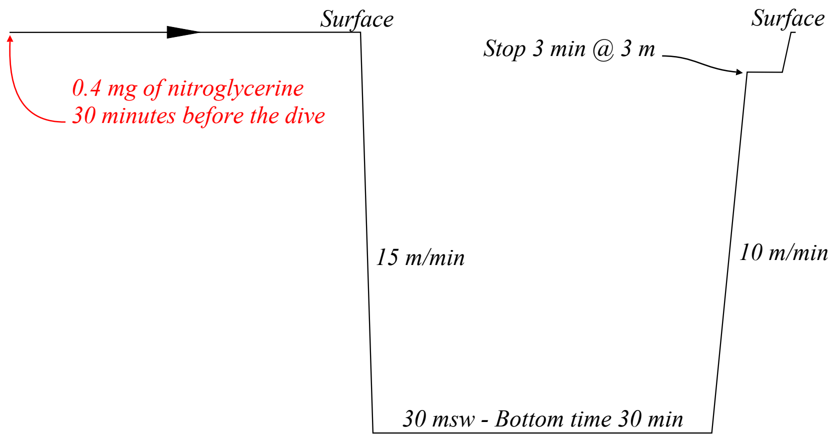
3.5.1 - Presentation

Two studies have been found. One is based on drug use and the other on beneficial food.

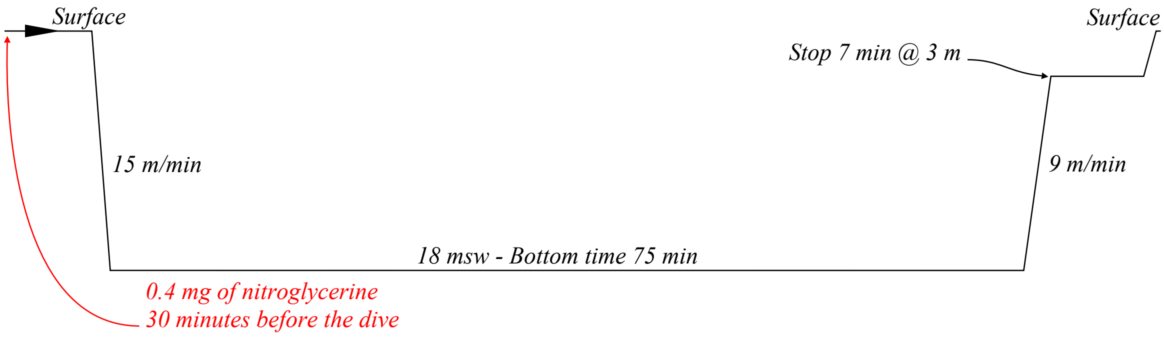
A. *"Exogenous Nitric Oxide and Bubble Formation in Divers"* is a study which aims to determine whether a short-lasting NO donor reduces bubble formation in humans performing standard dives and decompression procedures. It is published by Eljko Dujic, Ivan Palada, Zoran Valic, Darko Duplancic, Ante Obad, Ulrik Wisloff, & Alf O. Brubakk.

   Sixteen divers were involved in this study and assigned into two groups. One group performed two air dives at 30 msw in the sea. The second group performed two air dives at 18 msw in a hyperbaric chamber. The first dive for each diver served as the control dive.
   The short-lasting NO donor was 0.4 mg of nitroglycerine, taken by oral spray 30 minutes before the dive.

   - Open-water dives were organized to 400 kPa (30 msw) for 30 min breathing air. The ascent was performed at a rate of 10 msw/min with a 3-min stop at 3 msw. Exercises at an intensity corresponding to 30% of maximal oxygen uptake were performed during the bottom time.



   - Chamber dives consisted of compressing the divers to 280 kPa (18 msw) at a rate of 100 kPa/mn (10 m/min) breathing air. The bottom time was 75 min. No exercise was performed during the bottom time. The ascent rate was 90 kPa/min (9m/min) to 130 kPa (3 msw), where a 7 min stop was performed before ascending to the surface.



   The authors say that the present study demonstrated that intake of a short-lasting NO donor 30 min prior to a dive significantly reduced bubble formation following decompression after dives of different duration and depths in humans.
   They also say that they previously reported that administering a long-lasting NO donor several days or immediately before the dive similarly reduced bubble formation and increased survival significantly in rats.

On the opposite, in this study, the authors used a short-lasting “NO donor” that is active only for 15 minutes and which effects disappear prior to starting the dive. That would suggest that nitroglycerine only triggers a protective effect on bubble formation that lasts during the dive. The beneficial effect was similar in the dry chamber and in-water dive. The authors also say that together with their previous studies, it now appears well documented that NO prevent bubble formation in different mammalian species following different dive exposures.
To conclude, they say that this study and the previous ones demonstrated that exercise or drugs can reduce vascular bubble formation significantly.

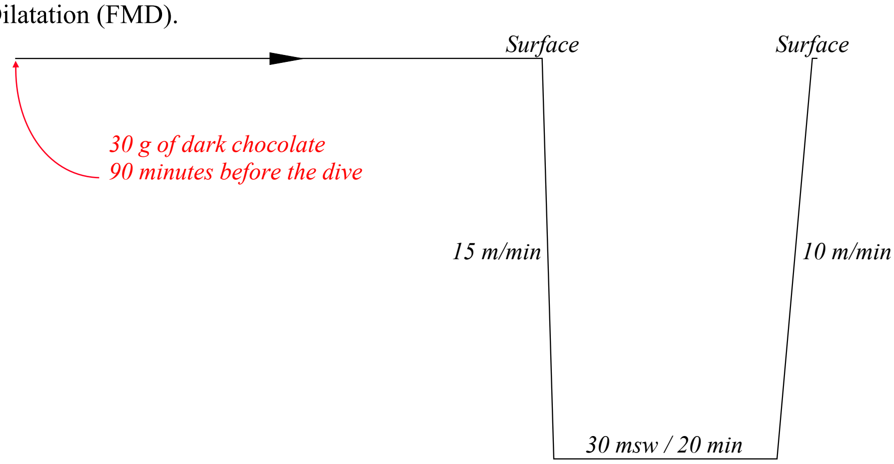
B. *“The effect of pre-dive ingestion of dark chocolate on endothelial function after a scuba dive”* is a study published by doctors Sigrid Theunissen, Costantino Balestra, Antoine Boutros, David De Bels, François Guerrero and Peter Germonpré.

As the title suggests, the aim of the study was to measure the effects of dark chocolate ingestion before a scuba dive on endothelial function.
It is based on the fact that polyphenols** contained in dark chocolate have the power to improve vascular health by stimulating the formation of vasoprotective factors such as Nitric Oxide (NO), leading to vasodilatation. They also improve vascular smooth muscle function by reducing oxidative stress. The reduction of the oxidative stress could reduce the NO degradation and thus prevent vasoconstriction.

- (**Polyphenols are natural organic compounds that act as antioxidants to neutralize harmful free radicals that would damage cells. They are also thought to reduce inflammation.)

The experimentations were organized as follows:

- Forty-two male scuba divers in perfect physical condition without previous cardiac abnormalities and not taking any cardio-active medication were involved. Their average age was 37 years. They were divided into two groups of equal size: A control group and a chocolate group.
- The participants were asked to refrain from strenuous exercise and nitrate-rich food for 48 h before the tests and not to dive for 72 h before testing. The chocolate group ingested 30 g of dark chocolate 90 minutes before the dive
- The divers performed a scuba dive at 33 msw for 20 minutes without a decompression stop in a calm, 8-m diameter pool. Water and air temperature were 33 °C and 29 °C respectively.
- The arterial endothelial function was assessed before and after diving by measuring brachial artery Flow-Mediated Dilatation (FMD).



The authors say that the results show a decrease in FMD after a standard scuba dive, consistent with the literature, whereas FMD increased post-dive after eating dark chocolate before diving. They conclude the following:

- Dark chocolate inhibits post-dive endothelial dysfunction, suggesting the presence of oxidative stress. Peroxinitrites* may not be the best biomarkers** to evaluate this stress in the current setting.
  Notes:
  - (Peroxynitrite* is an ion with the formula ONOO−. It affects mitochondria function and triggers cell death via oxidation and nitration reactions. Peroxynitrite is formed in any cell or tissue where the superoxide and nitric oxide radicals exist simultaneously.)
  - (Biomarkers**, also called "Biological markers", are indicators of some biological states or conditions. Biomarkers are often measured using blood, urine, or soft tissues.)
- The generally accepted hypothesis is that FMD is NO-dependent, but it was shown that FMD variations do not necessarily follow those of circulating NO. It seems that there are many potential factors that could contribute to variations in FMD.
- Dark chocolate could be an easy, inexpensive and tasty way to reduce the impact of diving on the cardiovascular system.

3.5.2 - Discussion

Drug use has been considered a promising way to improve decompression throughout diving history. Nitroglycerine is one among several molecules that have been studied without the obtention of clear conclusions. Undesired biochemical side-effects and interactions linked to such usage, as well as changing individual susceptibilities, are still impossible to predict and control. It is particularly impossible during diving operations without direct and close supervision by a medical doctor. Hence, pharmacological pre-conditioning should remain a subject of medical research only until robust shreds of evidence scientifically demonstrate harmlessness and effectiveness.

Apart from the fun side that the study on pre-ingested black chocolate was written by scientists living in Belgium, a country reputed for its quality chocolates, this article is an example of tentative pre-dive conditioning based on substances contained in food. Thus, although it is specifically focused on preventing decompression accidents, this study is among the large number of research programs highlighting the essential role of nutrition and dietetics in the primary prevention of diseases.

It must also be considered that several studies on using natural extracts for pre-dive conditioning have been made. For example, in an article intituled *"A red orange extract modulates the vascular response to a recreational dive: a pilot study on the effect of anthocyanins on the physiological consequences of scuba diving"*, published in March 2015, doctors C. Balestra, F. Cimino, S. Theunissen, T. Snoeck, S. Provyn, R. Canali, A. Bonina, and F. Virgili, verified the hypothesis that "anthocyanin", an antioxidant found in fruits and vegetables and known to reduce inflammation, can modulate some endothelial responses to high oxygen pressure associated with diving. All these pharmacological and food-related pre-conditioning hypothetical benefits are also linked to complex phenomenons that are not yet fully clarified. For these reasons, the authors of this study conclude by saying, *"Further studies are needed to establish if nutritional flavonoid (and in particular anthocyanin) supplementation can be a standard strategy to be advised not only to recreational or professional divers, but also to people exposed to high oxygen, either for therapeutic purposes or accidental collateral events"*. Thus, we also consider that it will take some time to clarify the questions resulting from these experiments before using them as references for diving pre-conditioning purposes.

Regarding specific diet, selected food, and nutrient extracts, our conclusion is that, as long as those have been proven to be harmless, we should consider their intake as being part of the basic and long-term healthy habits that every diver should implement to enhance fitness to dive and reduce individual susceptibility to decompression related diseases. We could qualify it as "long-term pre-conditioning". In addition to such a "baseline", the other methods that we have presented earlier in this Study 11 could provide the "medically fit diver" with an "additional short-term pre-conditioning" that might enhance the safety of the following decompression.

4 - Limitations, and results

4.1 - Limitations

One element that attracts the reader's attention is that the number of divers involved in these experiments seems modest if we consider that some of these procedures are suggested applicable. As a reminder, the number of divers involved and their average ages was as follows:

Study	*Nb of divers*	*Age*
Aerobic exercise before diving reduces venous gas bubble formation in humans	*13*	*22 - 38*
Aerobic exercise 2 hours before a dive to 30 msw decreases bubble formation after decompression.	*16*	*24 - 41*
Endurance exercise immediately before sea diving reduces bubble formation in scuba divers	*24*	*24 - 40*
Preventive effect of pre-dive hydration on bubble formation in divers	*8*	*36*
Pre-dive normobaric oxygen reduces bubble formation in scuba divers	*21*	*23 - 41*
Pre-treatment with hyperbaric oxygenation reduces bubble formation and platelet activation	*5*	*33.6*
Effect of in-water oxygen prebreathing at different depths on decompression-induced bubble formation and platelet activation	*6*	*?*
Predive Sauna and Venous Gas Bubbles Upon Decompression from 400 kPa	*16*	*38.4*
Pre-Dive Vibration Effect on Bubble Formation After a 30-m Dive Requiring a Decompression Stop	*14*	*29*
Pre-dive Whole-Body Vibration Better Reduces Decompression-Induced Vascular Gas Emboli than Oxygenation or a Combination of Both	*6*	*30–40*
Mini Trampoline, a New and Promising Way of SCUBA Diving Preconditioning to Reduce Vascular Gas Emboli?	*8*	*36*
Exogenous Nitric Oxide and Bubble Formation in Divers	*16*	*34.4*
The effect of pre-dive ingestion of dark chocolate on endothelial function after a scuba dive	*42*	*37*

Considering that, in a paper called *"Diving Data Bank: A unique tool for diving procedures development"*, published in May 1988, J P Imbert and M Bontoux said: *"A large volume of dives is now required to document any change in diving procedures: Scientists need it to validate their theories, diving companies to control their sites, government agencies to approve the procedures"*, and also the fact that the database COMEX contained over 150000 diving reports when this paper has been published, we are obliged to highlight the fact that it would have been interesting to have more divers involved in these pre-dive conditioning studies, and consequently more studies on the topics discussed. That would have provided the scientists with more cases to study and thus more means of investigation and correlation.
Note that the authors of these studies are aware of this problem. As an example, doctors Jean-Eric Blatteau, Emmanuel Gempp, Francois-Michel Galland, Jean-Michel Pontier, Jean-Marie Sainty, and Claude Robinet say: "*Our findings may be considered limited because of the small sample size. It would also be useful to perform a longer air dive in order to produce a significant and reproducible amount of bubbles"*.

As a possible reason for what I consider a lack of data, we can suggest that scientific research has a cost, and it is probably difficult for scientists to organize such experiments due to financial limitations.
Also, apart from a few exceptions, databases of the above size are missing today. The reasons for this are multiple but all linked, such as, for example, some perverse effects of global standardization and the disinterest of many governments and diving companies for science.

Another element to consider is the average age of the divers selected, which was approximately 30 - 35 years.
It is comprehensive that scientists testing assumptions select samples of volunteers in an optimal physical condition not to have to manage undesirable effects linked to health problems the diver may have.
It must be noted that the average age of the divers selected for these experiments is slightly younger than the average age indicated in the IMCA study *"Experience and employment profile of North Sea diving personnel: Profile for the years 2000 to 2003"*, where the average age recorded was approximately 39 years.

However, we must take into account that this IMCA study, which is nearly 20 years old, suggests that the percentage of divers above 50 years was increasing when it was published. For this reason, based on the fact that many divers in the category 30 - 35 years when this investigation was undertaken are still in activity in 2022, we have to consider that the population of divers could be older than in 2003 today. There is, unfortunately, no global study to confirm or infirm the aging trend perceived in 2003 in the north sea. Also, commercial diving activities have developed in countries where the population is younger than in Europe, which may impact statistics.

4.2 - Results

Again, we must consider that the purpose of these papers was to validate various concepts of predive conditioning, and not establish rules for commercial diving.
The table below logs the concepts that are thought applicable according to what is suggested below and according to the principle of precaution previously mentioned:

- Easy to implement,
- Not impacting the diving time
- Not affecting the interval between two dives
- Tested under scientific control.

Concept	*Study*	*Application*	*Suggested improvements*
Endurance exercise	*Aerobic exercise before diving reduces venous gas bubble formation in humans*	*Applicable anytime when cleared from deco penalties*	
	Aerobic exercise 2 hours before a dive to 30 msw decreases bubble formation after decompression.		
	Endurance exercise immediately before sea diving reduces bubble formation in scuba divers	*More experiments should be done before applying it.*	*Concept to be clarified*
Hydration	*Preventive effect of pre-dive hydration on bubble formation in divers*	*Applicable and already applied by most teams*	
Heat exposure	*Predive Sauna and Venous Gas Bubbles Upon Decompression from 400 kPa*	*Considered as experimental procedure*	*Concept to be clarified*
Oxygenation	*Pre-dive normobaric oxygen reduces bubble formation in scuba divers*	*Applicable with Standard Air*	*Application with nitrox and oxygen decompression*
	Pre-treatment with hyperbaric oxygenation reduces bubble formation and platelet activation	*Not applicable (Organizational issues)*	
	Effect of in-water oxygen prebreathing at different depths on decompression-induced bubble formation and platelet activation	*Not applicable (Organizational issues)*	
Vibration	*Pre-Dive Vibration Effect on Bubble Formation After a 30-m Dive Requiring a Decompression Stop*	*Applicable with Standard Air*	*Application with nitrox and oxygen decompression*
	Pre-dive Whole-Body Vibration Better Reduces Decompression-Induced Vascular Gas Emboli than Oxygenation or a Combination of Both	*Applicable with Standard Air and vibration only*	*Application with nitrox and oxygen decompression*
Jumping	*Mini Trampoline, a New and Promising Way of SCUBA Diving Preconditioning to Reduce Vascular Gas Emboli?*	*Applicable with Standard Air*	*Application with nitrox and oxygen decompression*
Specific substances	*Exogenous Nitric Oxide and Bubble Formation in Divers*	*Promising but to be tested further*	*Concept to be clarified*
	The effect of pre-dive ingestion of dark chocolate on endothelial function after a scuba dive	*Applicable anytime*	

Note that none of these concepts discussed has resulted in the publication of an algorithm applicable to quantify the possible reinforcement of decompression tables currently in use in the industry. That is linked to what is said in the introduction.
Linked to the above, although the benefit they provide cannot be doubted, none of these studies results in the reduction of decompression times. They have to be considered only reinforcements for the moment.
As highlighted in the table above and their descriptions, and for the reasons mentioned in the introduction and above, The

pre-dive conditioning solutions are to be used with “Standard Air” only for the moment. However, some of these concepts merit being developed to make them applicable with the decompression techniques we use:

- The effects of endurance exercise immediately before diving should be further tested as this study opens to a review of our knowledge and standards regarding this point.
- Normobaric oxygen conditioning should be tested with nitrox dives and oxygen decompression to ensure that the expected benefits of combined effects are real.
- Pre-dive vibration conditioning is a smooth method of preconditioning that gives lesser results if combined at the same time with oxygen. What would be the result if oxygen conditioning is made after, as suggested by doctors Imbert, Egi, Germonpré, and Balestra? Also, what would be the result if combined with Nitrox or oxygen stops?
- Jumping with the help of a mini trampoline gives excellent results and has the advantage that the sessions are ten times shorter than those of whole body vibration. Also, the equipment used is cheap and easy to carry. Its benefits with nitrox dives and oxygen decompression should be clarified.
- Drugs such as nitroglycerine are promising pre-dive conditioning methods. We think it is too early to implement them for the reasons already discussed. However, that would be possible after more tests and clarification of the procedure. Also, what would be the effects if cumulated with nitrox or oxygen stops?

As discussed before and demonstrated in the documents presented in this study, such experiments are to be performed by competent scientists with adequate medical and scientific support and validated by official bodies. Thus, a diving company cannot do it alone, except if it has the financial resources and the organization that allows it to group the above competencies, which can be done only by a few of them. However, small and medium size companies can group to initiate or join national or international research programs and support scientists in their work.
Nowadays, many commercial divers already improvise and intuitively implement self-designed pre-conditioning while their employer, particularly their diving supervisor, are not aware of it. Unorganized and somehow "undeclared" self-preconditioning might generate additional risks; for instance:

- Diver who implements unproven methods.
- Diver who implements a method that is inadequate for him on this given day, considering his health/fitness status at this given time and for this given dive. Several examples can be found.
- Impossibility to identify whether or not, actions implemented before dive could have contributed to an illness.

Also, in 2012, two medical doctors (Michael Bennett and Alf Brubakk) and two doctors in physiology (Constantino Balestra and Rune Djurhuus), all of them owning undisputed expertise in diving physiology and diving medicine, answered the Divers Alert Network (DAN) who wanted to update the understanding among the diving community, The question was: "Are there particular preconditioning practices divers can employ that may reduce their risk of DCS? Today, ten years later, the review of the existing literature collected for this CCO Study 11 shows that no further significant operational improvement has been achieved. It also shows the absence of leadership from the trade associations that have not been able to encourage and actively support dive schools, diving contractors, and divers to design longitudinal epidemiological studies and then a robust and anonymous database that would enable scientists to improve common knowledge in decompression and more mainly in diving medicine. Divers and diving contractors have the capabilities to access to and work closely with scientists, and then, to lead and design the future of commercial diving.

Considering the above, I hope this study could trigger discussion among companies and diving teams, raising awareness about the necessity of studying and learning more on the subject. Note that I have gathered and categorized chronologically numerous publications about this topic and others that are directly or indirectly linked. I have chosen them among the most relevant scientific papers and made them readily available via the website "Diving and ROV Specialists.com", which aims to provide relevant reliable information and trigger such discussions.

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