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ORIGINAL ARTICLE

Endurance exercise immediately before sea diving reduces bubble formation in scuba divers

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Abstract Previous studies have observed that a single bout of exercise can reduce the formation of circulating bubbles on decompression but, according to different authors, several hours delay were considered necessary between the end of exercise and the beginning of the dive. The objective of this study was to evaluate the effect of a single bout of exercise taken immediately before a dive on bubble formation. 24 trained divers performed open-sea dives to 30 msw depth for 30 min followed by a 3 min stop at 3 msw, under two conditions: (1) a control dive without exercise before (No-Ex), (2) an experimental condition in which subjects performed an exercise before diving (Ex). In the Ex condition, divers began running on a treadmill for 45 min at a speed corresponding to their own ventilatory threshold 1 h before immersion. Body weight, total body fluid volume, core temperature, and volume of consumed water were measured. Circulating bubbles were graded according to the Spencer scale using a precordial Doppler every 30 min for 90 min after surfacing. A single submaximal exercise performed immediately before immersion significantly reduces bubble grades ($p < 0.001$). This reduction was correlated not only to sweat dehydration, but also to the volume of water drunk at the end of the exercise. Moderate dehydration seems to be beneficial at the start of the dive whereas restoring the hydration balance should be given priority during decompression. This suggests a biphasic effect of the hydration status on bubble formation.

Keywords Diving · Decompression sickness · Bubble · Exercise · Heat · Hydration

Introduction

Decompression sickness (DCS) after sea diving is an effect of the formation of intra- and/or extravascular nitrogen gas bubbles when returning to surface pressure. Nitrogen bubbles cause a variety of symptoms ranging from mild skin rash to serious neurological symptoms (Francis and Gorman 1993). Assessment of venous gas emboli through Doppler ultrasonic monitoring is considered a valid indicator of decompression stress (Nishi and Kisman 1981). Indeed, it is generally accepted that the incidence of DCS is low when few or no bubbles are present in the circulation (Nishi and Kisman 1981). Preconditioning divers to reduce post-dive acute adverse effects has gained increased interest in diving medical research over the last few years. Known beneficial effects of exercise a few hours before diving (Blatteau and Boussuges 2007; Dujic and Valic 2008), oxygen breathing (Landolfi and Yang 2006), pre-dive hyperbaric sessions (Katsenelson and Arieli 2007), heat preconditioning (Blatteau and Gempp 2008), hydration (Gempp and Blatteau 2009), and some other approaches such as the administration of certain drugs, have further prompted this branch of research.

Intense physical exercise before diving has long been considered an additional risk factor for DCS (Vann and Thalmann 1993). It is suggested that muscle contraction

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and tissue movement produce gas nuclei, which lead to bubble formation and a corresponding increase in the risk of DCS (Harvey and Whiteley 1944). Recently, several studies have indicated that this notion needs rethinking.

Several recent studies give indication that it is beneficial to perform physical exercise before diving. However, there are very few human studies available. Dujic and Duplancic (2004) have reported recently that strenuous aerobic exercise 24 h before a simulated dive reduces venous bubble formation. In other human studies, it has been shown that a single bout of sub-maximal exercise followed 2 h later by simulated diving in a hyperbaric chamber (Blatteau and Gempp 2005; Blatteau and Boussuges 2007) or in open-sea water (Pontier and Blatteau 2007) significantly reduces the number of venous gas bubbles found in the right side of the heart. A recent study confirmed the beneficial effect of exercise taken 2 h but not 24 h before diving (Jurd and Tacker 2009).

At present, some theoretical explanations have been proposed to explain the beneficial effect of pre-dive exercise. The first is the reduction, before immersion, of the number of preexisting micronuclei from which gas bubbles grow (Blatteau and Souraud 2006). This reduction could be induced by endothelial nitric oxide (NO) production, an important vasodilator (Wisloff and Richardson 2004). In a recent study conducted within this framework (Dujić et al. 2006), 16 divers received 0.4 mg of nitroglycerine by oral spray 30 min before both a seawater dive and a simulated dive in a hyperbaric chamber. This study demonstrated that the intake of a short-lasting NO donor (i.e., nitroglycerine) reduced bubble formation following decompression after different dives. On the other hand, the sweat produced during physical exercise led to hypovolemia, thus causing a reduction in tissue perfusion during the subsequent dive, and therefore a reduction in the quantity of dissolved nitrogen (Blatteau and Boussuges 2007).

The main objective of this study is to assess if a single bout of aerobic exercise performed immediately before a dive can reduce venous gas emboli. This study is especially applicable as, in the daily activity of professional or military divers, there is no delay between exercise and diving, and as this combination has unfortunately not been the subject of prior investigation. We hypothesize that heat production, extracellular dehydration, and loss of body weight due to exercise affect bubble formation in a subsequent dive.

Methods

Subjects

The study population consisted of 24 healthy and physically active males with diving experience (300–3,000 dives). All characteristics of the population are presented in Table 1. None of them had experienced DCS in the past. The study was approved by the University's Institutional Review Board, and a written, informed consent was obtained before experimentation began.

Subject capacity determination

Subjects served as their own control. Exercise capacities were determined on a treadmill (HP Cosmos, Nussdorf-Traunstein, Germany) in a separate preliminary session. An incremental running protocol was performed in order to characterize maximal oxygen uptake ($\dot{V}O_{2\,\max}$) and assess the running speed corresponding to the ventilatory threshold (SVeT). After an 8 min warm-up run at 8 km h^{-1}, the speed was increased by 0.5 km h^{-1} every minute until volitional exhaustion. Gas and respiratory parameters were calculated breath-by-breath throughout the test by the software provided with the equipment (Cosmed K4b2®; Roma, Italy), which has been previously validated by Mc Laughlin (McLaughlin and King 2001). The ventilatory threshold (VeT) was calculated according to the method proposed by Wasserman and Whipp (1973). VeT is the point at which pulmonary ventilation and carbon dioxide output begin to increase exponentially during an incremental exercise test, and corresponds (but is not identical) with the development of muscle and blood acidosis. The following criteria were used to define the running speed at $\dot{V}O_{2\,\max}$: a respiratory exchange ratio (RER) >1.1, an increase in running speed without an O_2 increase, a [La_{bl}] >7 mmol l^{-1}, and attainment of the theoretical HR max value (220 − age) (Astrand and Rodahl 1986).

Protocol development

At least 2 days after attending the incremental test, open-sea dives were performed under two experimental conditions (Fig. 1) in a counterbalanced order: (1) a control

Table 1 Main characteristics of the population

	$n = 24$
Age (years)	32.4 ± 8.1
Body mass (kg)	62.4 ± 9.57
Height (cm)	169.7 ± 8.4
BMI	21.6 ± 1.6
Body fat (%)	18.1 ± 4.23
$\dot{V}O_{2\,\max}$ (ml min^{-1} kg^{-1})	48.1 ± 5.16
Speed at $\dot{V}O_{2\,\max}$ (km h^{-1})	14.2 ± 1.6
Speed at VeT (km h^{-1})	11.3 ± 1.6

Values are presented as mean ± SD

BMI, body mass index; $\dot{V}O_{2\,\max}$ maximal oxygen uptake; Speed at VeT, treadmill speed corresponding to the ventilatory threshold

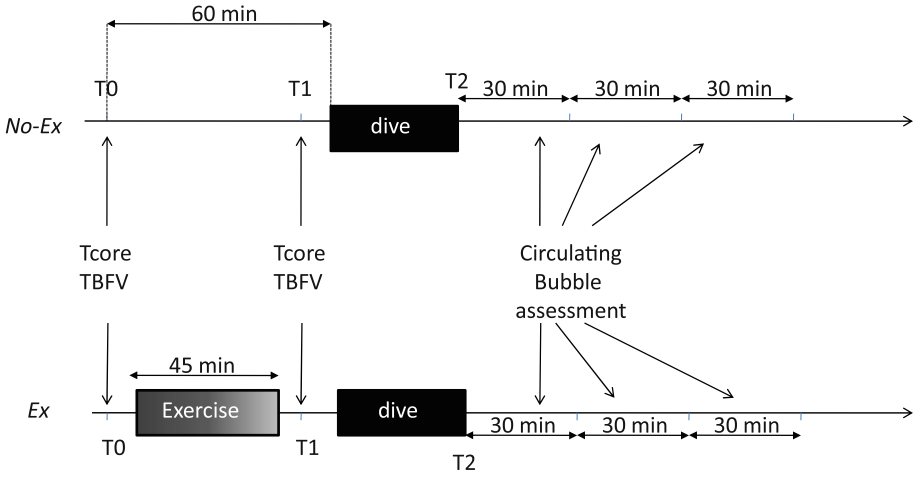

Fig. 1 Experimental protocol in both conditions: *No-Ex* no exercise before dive; *Ex* exercise before dive; Tcore, core temperature; TBFV, total body fluid volume. T0 = 60 min before the dive, T1 = immediately before the dive, T2 = immediately after the dive

condition without exercise before dives (No-Ex), (2) an experimental condition in which subjects performed an exercise before diving (Ex). Both experimental conditions were separated by a minimum of 48 h. All subjects were tested at the same time of day to minimize the effects of circadian rhythm. The subjects were asked to arrive at the diving center 1 h before immersion, having refrained from eating for at least 3 h before arrival. Under the No-Ex condition, during the hour before immersion, divers rested in an air-conditioned area (mean temperature = 21°C). Under the Ex condition divers ran for 45 min on a treadmill at a speed corresponding to their own VeT value (i.e., SVeT) in the same air-conditioned area, starting 1 h before immersion. A delay of 15 min was ensured between the end of exercise and immersion. Under the Ex condition, subjects were allowed to drink mineral still water freely during the 15 min between the end of exercise and the immersion. The volume of water drunk was noted. Under both conditions, after surfacing, the divers were not allowed to drink until the end of bubble assessment (during 90 min.).

Body composition, hydration, and temperature measurements

Body weight (BW) was measured using electronic scales (Tanita®, Hoofddorp, The Netherlands) and total body fluid volume (TBFV) recordings were estimated using a multi-frequency bioimpedancemeter (Nutriguard®; Data Input Frankfurt/Germany). Since it was not possible to take blood samples in the field, we chose to use the bioimpedancemeter method. Modern impedance measurement devices measure the electrolyte water contained in the tissues very accurately (Heyward 1996; Shirreffs 2003). It is generally agreed that the distribution of total body fluid volume (TBFV) is: Extra-cellular: ≈40% of TBFV (lymph, interstitial, trans-cellular, plasma) and Intracellular: ≈60% of TBFV. Under both conditions, TBFV was assessed three times: 60 min before the dive (T0), immediately before the dive (T1) and immediately after surfacing (T2) (Fig. 1). The Nutriguard® was also used to estimate the subjects' percentage of body fat.

Core temperature was monitored using an ingestible core body thermometer pill (Coretemp®, HQ, Inc. Palmetto, Florida, USA). The pill was swallowed on the morning of the experiment, at least 3 h before the experiment started. Under both conditions, Tcore was assessed twice: T0 and T1 (Fig. 1).

Diving design

The depth of each dive was set to 30 msw with 30 min bottom time. The ascent rate was set at 10 m min^{-1} with a decompression stop at 3 m for 6 min. The divers used air as breathing gas and were supplied with a diving computer (Suunto® D9, Helsinki, Finland). During the dive, subjects were told not to perform any strenuous exercise. The heart rate was checked using a Polar® Belt (S810i, Polar®, Helsinki, Finland). The divers were instructed to keep heart rate values between 90 and 110 bpm. The sea temperature at the surface and at the bottom varied between 25 and 28°C and all subjects were equipped with a 5 mm wet suit.

Post-dive bubble analysis

After completing each dive, the divers stayed on the boat without doing any exercise. Circulating bubbles were detected by an experienced operator using a continuous wave Doppler system equipped with a 5 MHz probe (Aqualab system GE, Milwaukee, WI) in the precordial area. Monitoring was performed by the same operator every 30 min for 90 min after surfacing and Doppler signals were stored on a laptop computer for subsequent blinded evaluation. During bubble measurement, the divers were supine for 3 min at rest.

The quantity of bubbles was graded using the Spencer scale (Spencer 1976) before being converted into a Kisman Integrated Severity Score (KISS). The KISS was assumed to be a meaningful linearised measurement of post-decompression intravascular bubble activity status that can be treated statistically (Nishi and Kisman 1981). The change in bubble production, an indicator of the beneficial role of physical exercise taken immediately before diving, was estimated using the ΔKISS values between the two experimental conditions ($\Delta\text{KISS} = \text{KISS No-Ex} - \text{KISS Ex}$).

Statistical analysis

Statistical tests were run using Sigma Stat software. Each participant served as his own control. In this study, only *non-parametric* tests were used because of their high severity and the small size of our sample. A normality test showed normal distribution for all variables (with exception of the Spencer scale). All data are expressed as means (±SD), except the Spencer scale values, which are expressed as medians (range).

For values obtained at two time points, a Wilcoxon's paired signed rank test was used. The simple relationships between KISS and different variables such as Tcore and TBFV were assessed using Spearman's rank order correlation tests. The level of significance was set at $p < 0.05$.

Results

Under the No-Ex condition, diving was associated with a significant reduction in TBFV between T1 and T2 (36.10 ± 5.57 vs. 35.1 ± 5.41 l; $p < 0.05$) (Fig. 2). Furthermore, under both conditions, a significant relationship was observed between KISS values and age ($n = 24$, $\alpha = 0.05$, $p = 0.003$) and body fat ($n = 24$, $\alpha = 0.05$, $p < 0.0001$), respectively.

Exercise effects

Exercising induced, one hand, a BW and TBFV values decrease and on the other hand a Tcore rise (Table 2). Furthermore, the fall in BW provoked by exercise was significantly correlated to the fall in TBFV ($n = 24$, $\alpha = 0.05$, $p = 0.037$).

Under the Ex condition, TBFV values were significantly lower after exercise (T1) than before (T0); (35.31 ± 5.43 vs. 36.10 ± 5.57 l; $p < 0.05$) (Fig. 2). On the opposite to No-Ex condition, no significant difference was found between TBFV values measured before (T1) immediately after the dive (T2) in Ex condition (35.3 ± 5.46 vs. 35.1 ± 5.43 l; p = NS) (Fig. 2).

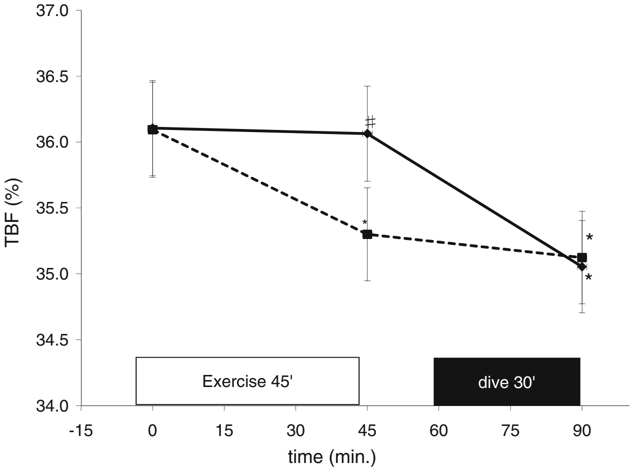

Fig. 2 Dehydration level expressed as TBFV (%) between no-exercise condition (*solid line*) and exercise condition (*dashed line*). *TBFV* total body fluid volume. Oral hydration after exercise prevented dehydration induced by diving. $^*p < 0.05$ from baseline; $^{\#}p < 0.05$ from the corresponding value in exercise condition. Values are presented as means (SD)

Table 2 Variation of body weight (BW), kg; total body fluid volume (TBFV), l; and core temperature (Tcore), °C; between T0 and T1, for all divers, and in both conditions

	Ex	No-Ex
BW (g)	−770 ± 280*	−52 ± 24
TBFV (ml)	−793 ± 350*	−42 ± 11
Tcore (°C)	−1.93 ± 0.77*	−0.09 ± 0.01

Values are presented as means ± SD

EX exercise condition, *No-EX* no-exercise condition

* If significant difference between T0 and T1 periods ($p < 0.05$)

Thus, at the end of both dives (T2), no significant difference in TBFV values was observed when comparing Ex and No-Ex conditions (35.11 ± 5.43 vs. 35.10 ± 5.50 l; $p = 0.2$) (Fig. 2).

There was also significant correlation between the volume of water drunk at the end of the exercise and the reduction in TBFV ($n = 24$, $\alpha = 0.05$, $p = 0.004$).

Under the Ex condition, maximum Spencer bubble grades were significantly lower than under No-Ex condition ($p < 0.0001$) (Fig. 3a). Furthermore, Kiss values under the Ex condition were significantly lower than under No-Ex (14.7 ± 12.3 vs. 25.5 ± 12.3, respectively, $p < 0.001$) (Fig. 3b). Only one diver recorded a higher grade of venous bubbles under the Ex condition compared to No-Ex.

There was significant correlation between ΔKISS values with the elevation of Tcore ($n = 24$, $\alpha = 0.05$, $p < 0.001$), reduction of TBFV ($n = 24$, $\alpha = 0.05$, $p < 0.001$) (Fig. 4), and fall in body mass ($n = 24$, $\alpha = 0.05$, $p < 0.05$), respectively, induced by physical exercise. There was also

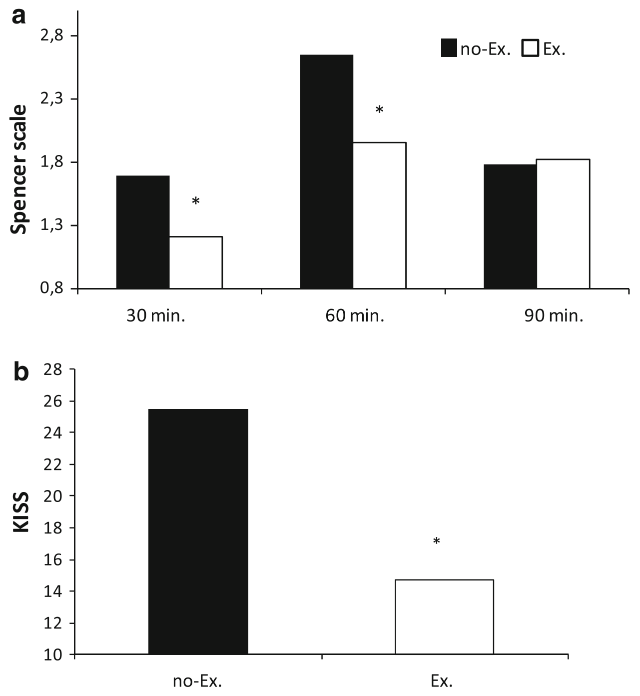

Fig. 3 **a** Post-dive circulating bubble Spencer scale (medians) detected 30, 60, and 90 min after surfacing for all divers in both conditions. *Significant difference between conditions, $p < 0.01$. **b** Post-dive circulating bubble detection (KISS) for all divers in both conditions. *Significant difference between conditions, $p < 0.01$

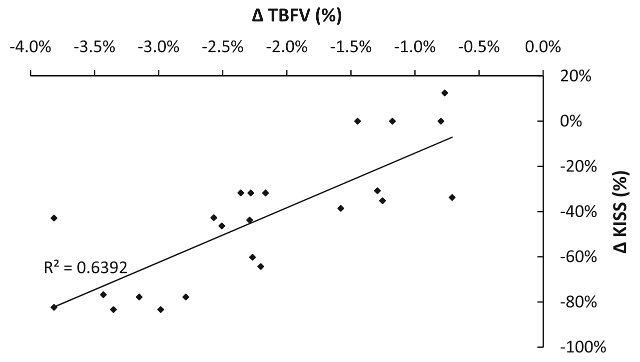

Fig. 4 Correlation between bubble reduction expressed as ΔKISS (%) and total body fluid volume reduction (ΔTBFV) induced by exercise. All data expressed as a percentage

significant correlation between the volume of water drunk at the end of the exercise and ΔKISS values ($n = 24$, $\alpha = 0.05$, $p = 0.06$) (Fig. 5).

Discussion

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.

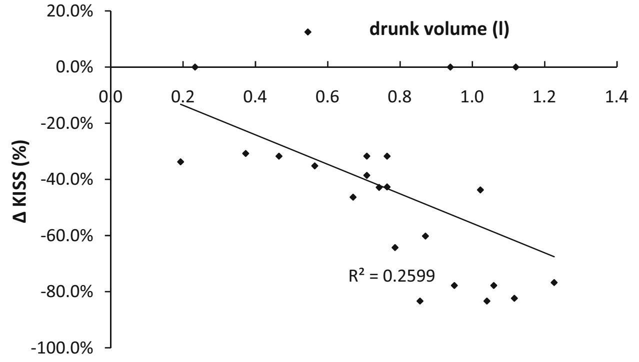

Fig. 5 Correlation between the volume of water drunk after exercise (l) and bubble reduction expressed as ΔKISS (%)

Previous studies have already observed this 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 decompression acutely increased bubble formation (Harvey and Whiteley 1944; Dervay and Powell 2002; Berge and Jorgensen 2005). Harvey and Whiteley (1944) showed that bullfrogs passively exercised via electrical stimulation prior to decompression at altitude developed more bubbles than sedentary controls. They suggested that exercise immediately before decompression could either increase the number of nuclei or increase their size, thus requiring less supersaturation to grow. Dervay and Powell (2002) showed that 20 subjects completing a knee-bend squat exercise suffered increased bubble formation when performed just prior to depressurization as compared with longer rest intervals. They suggested that the half-life of gas nuclei could be in the order of 1 h under these hypobaric conditions. Recently, Wisloff and Richardson (2004) and Berge and Jorgensen (2005) observed that intensive exercise up to 85–90% $\dot{V}O_{2\,\max}$ completed 30 min before a dive neither promotes nor reduces bubble formation and finally does not increase the risk of developing decompression sickness in rats.

However, most of these studies were performed in animals, using electrical muscle stimulation (Harvey and Whiteley 1944) or by applying much higher levels of exercise intensity than were used in our study (Wisloff and Brubakk 2001; Berge and Jorgensen 2005). 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 our study (running, endurance effort).

Furthermore, the result of this study shows irrespective of the experimental condition (Ex or No-Ex), there is a correlation between measured venous gas emboli and the subjects' age and body fat, respectively. The fact that increases in the diver's age and body fat percentage are associated with a higher production of circulatory bubbles has already been reported many times in previous scientific studies (Carturan and Boussuges 2002; Boussuges and Retali 2009).

Another important result of this study is to note that the reduction in venous gas emboli (expressed by "ΔKISS" values) induced by doing physical exercise immediately before diving is correlated, not only to the temperature (Tcore) rise, the volume of body fluid (TBFV) and body mass decrement induced by this exercise, but also to the volume of water drunk at the end of the exercise.

Several theoretical explanations can be proposed to explain the beneficial effect of pre-dive exercise immediately before immersion. Rigorous analysis of the kinetics of adaptive mechanisms implemented by the body during and after physical exercise and throughout immersion is fundamental to understanding the results of this study.

Effects of pre-dive exercise on sweat production and dehydration

Physical exercise completed at 21°C, which was the case in this study, is accompanied by an increase in Tcore. In order to avoid the risk of hyperthermia, this Tcore elevation is accompanied by increased sweat production, which induces a decrease in the TBFV. In this study, ΔTBFV is used as an indicator of exercise-induced hydration status impairment. As expected, TBFV values assessed at the end of exercise (T1), so immediately before immersion, were significantly lower under the Ex condition than under No-Ex.

We suggest that this dehydration caused by the physical exercise influenced and reduced the bubble formation measured after the dive.

Recent studies have shown that moderate dehydration induced by pre-dive exercise (Blatteau and Boussuges 2007) or a sauna session (Blatteau and Gempp 2008), effected a reduction in stroke volume, related to hypovolemia. This reduction might influence the inert gas load, and consequently decrease circulating bubbles. Indeed, the gas uptake of a particular tissue depends on both the rate of blood flow to the tissue and the rate of gas diffusion into the tissue from the blood. It may be that if the blood flow decreases, the rate of inert gas uptake would be slower and consequently bubble formation would be reduced (Blatteau and Boussuges 2007). We hypothesized that, in our study, blood flow might be reduced at the start and during the dive, thus limiting inert gas load and bubble formation afterwards. It also seems plausible that blood flow distribution to various tissues may affect uptake independently of total blood flow rate and such a response is likely after heat exposure and exercise.

On the other hand, if hypovolemia can decrease inert gas uptake, it can also reduce inert gas removal during the decompression phase. This is why we think that oral rehydration, just before immersions, has a complementary effect on attenuating bubble formation.

Effects of pre-dive exercise on oral rehydration before diving

Under the No-Ex condition in our study, the subjects recorded a significant fall in TBFV after the dive. This result matched the data in the literature indicating that immersion led to hypovolemia (Jimenez and Regnard 2009).

Because physical exercise induced a reduction in TBFV, and in order to prevent dehydration levels from rising too high, we allowed subjects under the Ex condition to rehydrate before diving (T1). Therefore, the dehydration linked to physical exercise was fully compensated by drinking water. We noted a relationship between the quantity of water drunk and delta TBFV values, implying that the subjects who were the most dehydrated by exercise were the ones who felt the most thirst and therefore drank the most water.

However, drinking water does not immediately alter volemia. It was demonstrated that, with plain water, the transfer of fluid from the stomach to the blood circulation takes place gradually over several tens of minutes (Gisolfi and Duchman 1992; Gisolfi and Summers 1992). Thus, under the Ex condition this extrinsic water compensation prevented the combined effects of exercise and immersion on dehydration. Indeed, during the 30 min dive, water in the stomach gradually passed into the bloodstream, progressively increasing TBFV values to the point where, at the end of the diver, they reached similar values between the two experimental conditions (Fig. 2).

We suggest that this oral hydration before diving influenced bubble formation. Gempp and Blatteau (2009) previously found that pre-dive oral hydration decreases circulatory bubbles, thus proposing a relatively simple means of reducing the risk of DCS. Prehydration slowed dehydration and prevented hypovolemia induced by the diving session. The authors speculated that fluid ingestion resulting in hypervolemia might impede the lowering of cardiac preload induced by the diving session. These findings are in agreement with a recent study reporting that the consumption of 400 ml of an isotonic beverage could prevent dehydration and increased blood viscosity during prolonged sitting in a dry environment, by attenuating negative water balance and hypovolemia (Doi and Sakurai 2004). Previous observations have also shown that a supine body position and other such interventions that increase central blood volume and cardiac preload, significantly increased the rate of inert gas washout (Balldin 1973). Consequently, it is plausible that pre-dive oral hydration might result in more rapid elimination of excess inert gas dissolved in body tissues during decompression, thus reducing circulating bubbles.

To summarize, under the Ex condition, the low hydration level during the first part of immersion would reduce inert gas concentration during diving (by a fall in regional tissue perfusion), while improvement of this hydration level (by after-exercise water ingestion), specifically during decompression, would promote inert gas elimination through high quality tissue perfusion.

Effects of pre-dive exercise on heat production

Exercise is associated with metabolic heat production (Adams and Fox 1975). In our study, mean Tcore just before immersion (T1), under the Ex condition was significantly higher [+1.9 (min 0.75; max 3.15)°C] than under the No-Ex condition.

It is now generally accepted that the phase of the dive determines the effect the thermal state has upon decompression; but so far, the conclusions of scientific studies on this subject are contradictory.

In the opinion of some authors, divers exposed to warm conditions during the first part of immersion, absorb more nitrogen at depth, and so increase their risk of decompression sickness compared with divers exposed to cold water conditions (Balldin 1973). On the other hand, another study concerning divers has demonstrated that the deleterious effects of warm conditions during bottom time were less pronounced than the beneficial effects of warm conditions during decompression (Gerth and Ruterbusch 2007). Finally, a recent animal experiment did not confirm this data relative to the risk of DCS (Fahlman and Kayar 2006).

Since heat exposure at depth should increase bubble formation, we believe that the thermal effects of pre-dive exercise sessions are not directly involved in reducing bubble formation in our study.

Pre-dive exercise and endothelial nitric oxide production

Another possible mechanism by which aerobic exercise has a protective effect 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 (Higashi and Yoshizumi 2004). According to the study by Roberts and Barnard (1999), acute exercise increased nitric oxide synthase activity immediately after 45 min of exercise. Moreover, Wisloff and Richardson (2004) have previously shown that nitric oxide administered immediately before a dive reduces bubble formation.

Limitations

For practical and technical reasons, our study focused on measuring hydration status and did not study the effects of endothelial NO or HSP (heat-shock proteins) values.

In future it would be interesting to monitor body temperature throughout the dive and take ultrasound measurements of cardiac output during decompression.

Conclusion

A single 45 min session of sub-maximal exercise performed immediately before immersion significantly reduces venous gas emboli. Surprisingly, to the best of our knowledge, our study is the first to note a significant relationship between these two parameters and the reduction in circulating bubbles, thus revealing the protective role of pre-dive exercise immediately before immersion.

This study has practical benefits because it confirms the role of early hydration during or just after exercise in potentiating the beneficial effects of exercise on decompression.

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.

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