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FACTORS INFLUENCING OF THE DECOMPRESSION RISK UPON DIVERS

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Abstract - The most likely factor initiating Decompression Sickness (DCS) is believed to be the formation of bubbles in the blood and the tissues. Bubbles form during decompression as a result of supersaturation of the dissolved gas, from the gas nuclei present in the tissues even at normal atmospheric pressure and provoke the symptoms of DCS. Ascent rate is known to be a critical factor for DCS risk. Individual factors, such as age, weight, fat tissues are also recognized for their implication in DCS risk. The aim of this study was to contribute to enhanced safety of divers, by measuring the rate of off-gassing by means of Doppler after decompression and relate it to ascent rate and some individual factors. We showed a clear influence of age and weight on the grades of bubbles. Also, we are making the detections of the grades of circulating bubbles every ten minutes after surfacing, to measure the kinetics of the bubbles. We investigated that bubbles generally peak about 30 ÷ 40 min after the end of the dives.

Keywords: Decompression sickness, ascent rate, individual factors, Doppler detection

I. INTRODUCTION

Forming of gas bubbles in the blood and the tissues is considered to be the most probable factor for initiating the Decompression sickness (DCS).During the decompression, as a result of the supersaturation with gas, dissolved in the tissues, from the available at normal atmospheric pressure "silent bubbles" there get formed bigger bubbles, which cause the symptoms of DCS.The ascent rate is known to be a crucial factor in the risk of developing DCS[5, 6]. The individual factors, such as age, weight and fat tissue, also influence the decompression risk[7, 8, 9].

The purpose of this research is to contribute to increasing the safety of diving for divers. With the usage of Doppler for measuring the availability and the degree of the circulating gas bubbles in the vein blood circulation and for reading the impact of the decompression speed as well as several individual factors, such as the age of the diver, the weight and the percentage of fat tissues, the risk degree of developing DCS is determined. Also, through detecting the bubbles at every 10 minutes after ascending to the surface, their kinetics are measured.

II. MATERIALS AND METHODS

*Divers:*32 divers took part in the research – men from the Navy, who had undergone preliminary medical examination for diving admission, and very well experienced in diving. Average age: 34.5 ± 12.3 years, average weight: 82.8 ± 11.2 kg, average height: 178.3 ±7.2 cm.

*Dives:*64 dives have been done. The divers conducted two dives to 30 meters for 30 minutes, with a 24 - hour interval over the surface. The descent rate is 25 ÷ 30 m/min and this time is included in the bottom time.The divers swim normally at the bottom, not doing any hard physical work.The ascent rate of the first dive is 9 m/min (*U.S. Navy Standard Air Decompression Table – 2001*), and for the second – 18 m/min (*Marina Militare Italiana – Tabella di decompressione preventive per l'immersione standard ad aria*). The diving profile and rate of ascent are controlled by a chronometer, pressure gauge and dive computers (*SuuntoDX and Maester Pro Beuchat*). The ascent time to the first decompression stop is 180 seconds for the first dive (9m/min ascent rate) and 90 seconds (18m/min ascent rate) for the second. The difference in the ascent time (Δt) to the first decompression stop is: Δt=90 Sec. The decompression stops, according to the two decompression tables, have been done as follows: 3 minutes at 3 meters.

The dives have been done in Varna in the period between August 2015 and September 2016 at different climatic conditions.The temperature of the water during this period varies between 7°C ÷ 25°C at the surface and 6°C ÷ 15°C on the bottom.

*Registering of gas bubbles:*Bubbles are detected in the precordial region (at the exit of the right ventricle, at 1 ÷ 2 cm under the pulmonary valve), with the usage of the "K-M code", invented by Kisman and Masurel [2]. In accordance with Nishi [1], that the peak of bubbles is mainly registered within 60 minutes after the end of the dives, the records of the subjects are taken every 10minutes within 1 hour after surfacing. After that, two times in 30 minutes.

A bi-directional Doppler has been used (*BIDOP ES 100 – V3*), made by the Japanese company *HADECO*, with 2MHz transducer.The registered signals have been recorded for a following-up more precise comparative computer evaluation. For annihilating side noises and maximal avoiding of subjective faults, a special computer program (*Wave Purity*

Professional) has been used, which allows a more precise determination of the parameters and the degree of bubbles.

*Evaluation of the individual factors:*One of the effects of age is the increasing amount of fat tissue. Weight is a less objective criteria for reflecting the body construction in comparison with the percentage of fat tissue (%FT). For each diver %FT has been measured indirectly with an electrical impedance apparatus (*TANITA – TBF – 300 – M/MA*).

In the research a connection has been made between the grade of gas bubbles in the vein blood circulation of every subject and individual factors, as well as the interconnections among separate factors. The subjects with available bubbles grade ≥ 2 have been classified as "bubble producers" (BP) and their percentage has been calculated for each ascent rate.In order to determine the percentage of BP and to analyze the influence of various factors, divers have been divided into the following groups:

1. Age > 40 years; age < 40 years
2. Weight ≥ 76 kg; weight < 76 kg
3. % FT > 20; % FT < 20

The effect of ascent rate, age and weight on the grade of the bubbles are evaluated through an analysis of the variance.

The analyses were carried out using the Statistical Package for the Social Sciences (SPSS)version 19.

Ethical Considerations: Throughout the researchprocess have observed the ethical principles to protect human rights in accordance with the Declaration of Helsinki.

III. RESULTS AND DISCUSSION

Through research of the grade of bubbles the following results have been recorded:

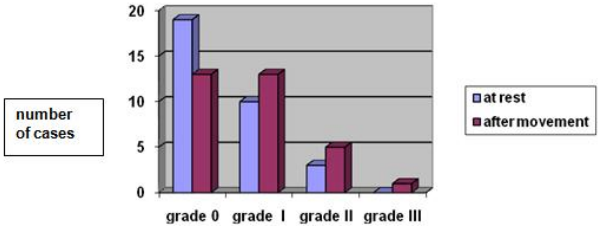

Fig.1. Results of bubbles at ascent rate 9m/min

At the ascent rate 9 m/min at rest, there have been registered only 3 out of a total of 32 divers with II bubble grade (there wasn't any higher) and they were determined as "bubble producers" (BP). Their percentage in comparison with the other divers is 9.37%. The records taken after performing specificmovements show that 6 subjects have been determined as "BP" and this makes 18.75% of the total number of divers.

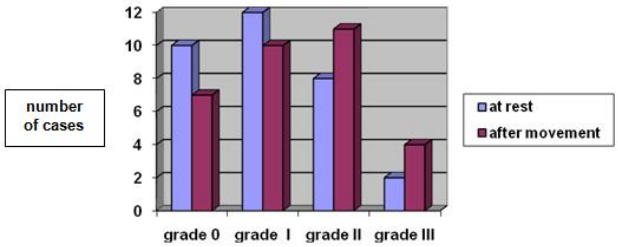

Fig.2. Results of bubbles at ascent rate 18m/min

At ascent rate 18 m/min and at rest the percentage of "BP" is 31.25 % or, that is 10 subjects, while at measuring after movement there have been registered 15 divers with II and higher grade of bubbles and they were defined as "bubble producers" (BP). Their percentage in comparison with the rest of the divers is 46.88%.

The registered bubbles are grouped as follows:

- 9 m/min, age > 40: 10 subjects / 3 BP = 30.0 %
- 18 m/min, age > 40: 10 subjects / 7 BP = 70.0 %
- 9 m/min, age < 40: 22 subjects / 3 BP = 13.6 %
- 18 m/min, age < 40: 22 subjects / 8 BP = 36.4 %
- 9 m/min, age > 40, weight > 76 kg: 9 subjects / 3 BP = 33.3 %
- 18 m/min, age > 40, weight > 76 kg: 9 subjects / 7 BP = 77.8%
- 9 m/min, weight > 76 kg: 21 subjects / 5 BP = 23.8 %
- 18 m/min, weight > 76 kg: 21 subjects / 12 BP = 57.1 %
- 9 m/min, weight < 76 kg: 11 subjects / 1 BP = 9.1 %
- 18 m/min, weight < 76 kg: 11 subjects / 3 BP = 27.3 %
- 9 m/min, %FT > 20: 20 subjects / 5 BP = 25.0 %
- 18 m/min, % FT> 20: 20 subjects / 12 BP = 60.0 %
- 9 m/min, % FT < 20: 12 subjects / 1 BP = 8.3 %
- 18 m/min, % FT < 20: 12 subjects / 3 BP = 25.0%

Table 1: Relation between the grades of bubbles and individual factors

bubble grade at ...	age		weight		% FT		weight>76kg and> 20% FT	
	r	p	r	p	r	p	r	p
ascent rate 9 m/min	.323	.071	.321	.073	.0317	.077	.380*	.032
ascent rate 18 m/min	.369*	.038	.488**	.005	.407*	.021	.504**	.003

Table 2: Relation between the individual factors

	age and weight	age and % MT	weight and % MT
r	.346	.928**	.453**
p	.052	.000	.009

Therefore, in the increased risk group, with weight > 76 kg and FT > 20% there exists a strong statistically considerable positive correlation with:

- age: r = .383* p = .031
- weight: r = .934** p = .000
- % FT: r = .485** p = .005

*The correlation is significant at p < 0.05

** The correlation is significant at p < 0.01

The comparison of bubble kinetics for the two different ascent rates (9 m/min and 18 m/min) is graphically presented at Fig.3

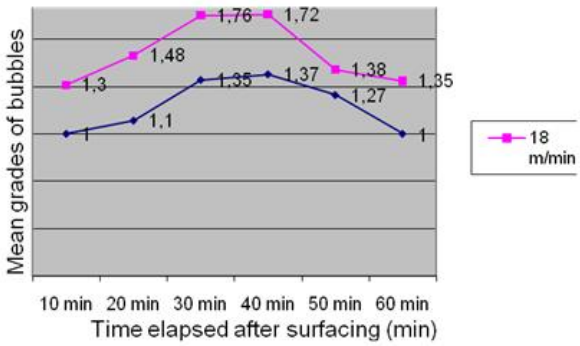

Fig. 3. Comparison between the kinetics of the bubbles for the twoascent rates investigated: 9 m/min and 18 m/min

It was accounted that at both ascent rates the peak of bubbles appears between the 30th and the 40th minute after the end of the dives.

The results clearly demonstrate the influence of ascent rate, age, weight and percentage of fat tissue over the divers' production of bubbles. The previous experiments show that the grade of precordial bubbles can be used as a means of predicting the probability of decompression sickness [3, 4]. Therefore, there may be made a connection between the percentage of "bubble producers" and the likely risk of DCS.

On the basis of the recorded results it was concluded that this correlation is more clearly expressed among the divers, aged over 40 and among the divers, weighing more than 76 kg, having a percentage of fat tissue over 20 %. A higher grade of bubbles has been registered among the mentioned above in comparison with the divers from the other groups.

The higher ascent rate (18m/min) causes a greater decompression stress in comparison with the lower rate of 9 m/min, as this correlation is again more clearly highlighted and is statistically significant in the groups of older divers and overweight divers, with a high percentage of fat tissue. As it was expected the records taken after movement, show a higher grade of bubbles, compared with the registered at rest.

IV. CONCLUSIONS

1. The research shows that using the Doppler to discover gas bubbles in the vein blood circulation is a reliable and a plausible method of evaluation of the decompression risk.
2. The method gives an opportunity to evaluate objectively various conditions and individual factors, which increase the risk of developing Decompression Sickness, and this allows determining personally the physical adaptability and condition of different divers.
3. The higher ascent rate leads to a higher risk of appearance of decompression pathology.
4. Divers over 40 yearsold and overweight divers are exposed to a greater decompression risk.
5. Determining the bubble grade allows undertaking preliminary measures for preventing the appearance of decompression pathology.

REFERENCES

1. Nishi R.Y. (1993). Doppler and ultrasonic bubble detection. In PB Bennett and DH Elliott (Eds) "*The Physiology and Medicine of Diving"*. 4th ed; WB Saunders Company Ldt, London pp 433-453.
2. Kisman K., Masurel G. (1983). Method for evaluating circulating bubbles detected by means of the Doppler ultrasonic method using the "KM code", *C.E.R.S.T.M. – Direction des Constructions et Armes Navales*, 83800 Toulon Naval France.
3. Nashimoto I. & Gotoh Y. (1978). Relationship between precordial doppler ultrasound records and decompression sickness. *In Proc. Sixth Symp. Underwater Physiology*, pp. 497-502. Ed. C.W. Shilling & M.W. Beckett. Bethesda, Md: FASEB.
4. Kisman K.G., Masurel D., Lagrue J., Le Pechon (1978). Evaluation de la qualite d'une decompression après exposition hyperbare basee sur la detection ultrasonore des bulles. *Med. Aero. et Spat. Med. Sub. et Hyp*. Vol 17, № 67, pp. 293-297.
5. Pollard G.W., Marsh P.L., Fife C.E., Smith L.R. & Vann R.D. (1995). Ascent rate, post dive exercise and decompression sickness in the rat. *Undersea and Hyperbaric Biomed.* 22: 367-376.
6. Carturan D., A. Boussuges, G. Habib, B. Gardette, J.M. Sainty (1996). Influence of ascent rate on venous bubbles detected after recreational dives. *Proc. Internat. Joint Meeting on Hyperbaric and Underwater Med.* A. Marroni and G. Oriani (eds.), Milan, pp. 499-503.
7. Boussuges A., P. Ambrosi, G. Habib, D. Carturan, B. Gardette, J.M. Sainty (1996). Detection of circulating bubbles with 2D echocardiography and pulsed Doppler. *Proc. Internat. Joint Meeting on Hyperbaric and Underwater Med.* A. Marroni and G. Oriani (eds.), Milan, pp. 495-497.
8. Lam T.H. & Yau K.P. (1988). Analysis of some individual risk factors for DCS in Hong Kong. *Undersea Biomed. Res.* Vol. 16.
9. Carlioz M., Comet M., Gardette B. (1985). About individual factors influence in man on the bubble formation in air diving after decompression. *XI th EUBS Congress. Goteborg*
10. Blogg S. L, Gennser M., Møllerløkken A., Brubakk A. O.: Ultrasound detection of vascular decompression bubbles: the influence of new technology and considerations on bubble load. *Diving Hyperb Med.*,2014; 44(1):pp 35-44.
11. Doolette D. J., Gault k. A., Gutvik C. R.: Sample size requirement for comparison of decompression outcomes using ultrasonically detected venous gas emboli (VGE): power calculations using Monte Carlo resampling from real data. *Diving Hyperb. Med*, 2014; 44: pp 14-19.