

Effect of a single pool dive on pulmonary function in asthmatic and non-asthmatic divers

Dragana Ivkovic, Marija Markovic, Bozica Suzic Todorovic, Costantino Balestra, Alessandro Marroni and Milos Zarkovic

Abstract

(Ivkovic D, Markovic M, Todorovic BS, Balestra C, Marroni A, Zarkovic M. Effect of a single pool dive on pulmonary function in asthmatic and non-asthmatic divers. *Diving and Hyperbaric Medicine*. 2012;42(2):72-77.)

Introduction: The aim of this study was to evaluate the effect of a single, shallow, swimming pool scuba dive on pulmonary function in divers with asthma as compared to controls. Opinions concerning the risks of diving with asthma are still contradictory and inconclusive in the diving community.

Methods: Baseline pulmonary function tests (PFTs) were performed on a group of 22 divers with asthma and on a control group of 15 healthy divers. The same PFTs were repeated within 10 minutes after a single pool dive, at 5 metres' depth for 10 minutes. PFTs were measured using a portable Jaeger SpiroPro™ device. Student's paired t-tests and linear mixed effects model comparisons and interactions within the groups were used in the data analysis.

Results: Divers with asthma initially presented significantly lower values of FEV₁/FVC%* ($P < 0.01$), FEF₂₅* ($P < 0.01$), FEF₅₀* ($P < 0.001$), FEF₇₅* ($P < 0.01$) and FEF₂₅₋₇₅* ($P < 0.001$) compared to controls. There were significant reductions in FEV₁ ($P < 0.01$), FEV₁/FVC% ($P < 0.05$), FEF₅₀* ($P < 0.01$), FEF₇₅* ($P < 0.05$) and FEF₂₅₋₇₅* ($P < 0.001$), in the asthma group after the dive as compared to the control group. PEF was initially lower, although not significantly, in the asthma group and did not change significantly after the dive in either groups ($P > 0.05$).

Conclusions: A single, shallow, pool scuba dive to 5 metres' depth may impair function of small airways in asthmatic divers. More studies are necessary to estimate the risks when divers with asthma practise scuba diving. PFT results should be analysed after replicated dives in deeper pools and controlled open-water conditions.

Key words

Lung function, pulmonary function, scuba diving, asthma, research

Introduction

The population of divers with asthma is growing and many asthmatics dive regularly, even though some diving physicians do not give them approval to dive. A problem is that many divers with asthma deny any history of asthma while answering medical questionnaires. It is known that 10% to 15% of children have some history of recurrent wheezing, while 5% to 8% of adults are diagnosed as 'asthmatics'. Survey data show a similar prevalence of asthma in recreational divers as in the general population.¹

People with asthma represent a heterogeneous group of patients who may experience a wide range of both frequency and severity of symptoms, such as coughing, wheezing, chest tightness and/or shortness of breath. The most common type of diving, with open circuit scuba, can expose the participant to several important asthma triggers. The diver is exposed to cold and physical stress, with possible exertion and anxiety. The breathing gas is cold, dry and dense, which increases respiratory resistance. Diving equipment imposes both increased inspiratory and expiratory resistance, resulting in increased work of breathing. Theoretically it might be

expected that all these factors would provoke bronchospasm, which might increase the risk of pulmonary barotrauma and reduce exercise capability.

Asthma remains the most controversial medical condition affecting recreational divers. Current criteria for pulmonary fitness to dive in people with asthma are also inconsistent and controversial. Asthma has long been considered a strong contra-indication to scuba diving. However, consensus in the diving medical community has changed radically since the 1990s, especially after the UHMS Meeting in 1995, at which a more liberal attitude was adopted that some asthmatics could be certified for scuba diving under certain circumstances.^{2,3}

There are still many different medical opinions with recommendations ranging from 'never – once asthmatic, always asthmatic', to 'no diving with a history of asthma over the previous five years', to 'no diving within two days of wheezing'.⁴ The most consistent consensus among diving experts is that people whose episodes of bronchospasm are associated with exercise, anxiety or the inhalation of cold air should not dive. Despite the theoretical objections

* **Footnote:** VC_{in} – inspired vital capacity; FEV₁ – forced expiratory volume in 1 sec; FVC – forced vital capacity; FEF₂₅ – forced expiratory flow rate at 25% of FVC; FEF₅₀ – forced expiratory flow rate at 50% of FVC; FEF₇₅ – forced expiratory flow rate at 75% of FVC; FEF₂₅₋₇₅ – mean forced expiratory flow rate between 25 and 75% FVC; PEF – peak expiratory flow rate.

and speculations related to increased risk of pulmonary barotrauma, there is no solid evidence that asthma carries an increased accident rate. Epidemiology is also inconclusive and data are mainly based on surveys of active divers and the retrospective compilation of accident information.

A Divers Alert Network (DAN) retrospective review (reported only as a meeting abstract), aimed at assessing the risk of asthma inducing arterial gas embolism (AGE) and type II decompression sickness, suggested an approximately twofold increase in risk for divers with asthma, but this did not reach statistical significance. Other surveys have shown that scuba diving deaths linked to asthma were infrequent.^{5,6} DAN reported 96 recreational scuba diving fatalities in 1992 and concluded that diabetes mellitus and bronchial asthma did not appear prominently in these series.⁷ Recent annual reports have offered similar conclusions.⁸ In contrast to the USA and UK experiences, asthma was reported as a contributing factor in 8% of 124 scuba diving deaths in Australia and New Zealand.⁹ In a study of 17,386 dives, there were no reported cases of serious diving injury.¹⁰ Another study (again only reported as a meeting abstract) did not indicate any statistically significant decrease in the peak expiratory flow rates in people with asthma after a single introductory open-water dive to 5 metres' depth for 30 minutes.

In order to better assess the possible risks of asthma when scuba diving, we decided to evaluate lung function in a real-life situation, immediately after a single, swimming pool scuba dive, a diving pattern experienced by all prospective divers, in a group of divers with asthma and a control group with no history of bronchospasm.

Methods

The subjects were 22 divers with asthma and 15 healthy control divers, who were members of various diving clubs in Belgrade. All divers completed a questionnaire relating to their medical history and diving habits, and signed an informed consent form. Tests were conducted in accordance with the Declaration of Helsinki and were approved by the Ethics Committee of the Faculty of Medicine, the University of Belgrade, Serbia.

STUDY GROUPS

The control group comprised healthy divers without any serious respiratory disease in their medical history. The group of divers with asthma was relatively heterogeneous, and none had ever experienced any breathing difficulty while diving. All asthmatics declared that their previous episodes of wheezing were not associated with exercise, anxiety or the inhalation of cold air. For at least 15 days before the dives, all asthmatics were in a stable condition, without presenting any breathing difficulties. There were no smokers in either of the groups.

On the basis of their medical history and documentation, the divers with asthma were classified into three categories. There were eight participants classified as 'childhood asthma', all free of any symptoms during the previous 5–10 years. There were 10 participants classified as 'mild intermittent asthma', with symptoms less than twice a week and with a normal level of activity between brief exacerbations. There were four divers classified as 'mild persistent asthma', with symptoms twice or more times a week, but less than once a day, whose activity might be affected by exacerbations.¹¹ Eight of these 22 asthmatics (two with a history of childhood asthma, two with mild intermittent asthma and four with mild persistent asthma) had undergone medical assessment of fitness to dive in our facility before the commencement of their first diving course. Another six asthmatic divers (two childhood asthma and four mild intermittent asthma) requested our medical advice during their diving career, while the remaining eight asthmatics (four childhood asthma and four mild intermittent asthma) never requested any medical opinion on their fitness to dive.

Thus 14 of the divers with asthma had previously been assessed in our facility, when they performed a 43 cm step test for 3 minutes (according to the UK Sports Diving Medical Committee guidelines), followed by pulmonary function tests (PFTs) at 10 minutes after exercise.¹² There was no decrease in FEV₁ by more than 10% from the baseline value or in other respiratory parameters measured in these divers. Coincidentally, we recorded an improvement in small airways function and a statistically significant increase in FEF_{25–75}, with the result that these asthmatics had been cleared at that assessment to practise scuba diving.

PULMONARY FUNCTION TESTS

Baseline PFTs were measured in both groups 10 minutes before the study dive. Spirometry and flow-volume loop measurements, including PEF, VC_{in}, FVC, FEV₁, FEV₁/FVC ratio, FEF₂₅, FEF₅₀, FEF₇₅, and FEF_{25–75} (see footnote p. 72 for definitions), were performed according to the 1993 European Respiratory Society (ERS) recommendations, and updated according to the 2005 ATS/ERS standardisation of spirometry.^{13,14} PFTs were assessed by means of a portable Jaeger SpiroPro™ device and the results were corrected to BTPS. Testing was undertaken with the diver in a standing position, and the results of at least three acceptable flow-volume measurements were used for analysis. The same PFTs were repeated 10 minutes after the dive.

DIVE PROTOCOL

Test dives were performed in an indoor, chlorinated swimming pool. Chlorine concentration was set to 0.4 mg L⁻¹, the pH value to 7.3 and water temperature was 25°C. The depth of the dive was 5 metres and duration was 10 minutes. Diving was performed in a relaxed manner, with minimal

underwater work. The approximate speed of underwater swimming, mainly in a horizontal position, was 15–20 m min⁻¹, which corresponded to mild physical activity.

STATISTICAL ANALYSIS

Student's paired t-tests were applied after normality testing of the samples by means of the Kolmogorov Smirnov test. All data are expressed as mean (SD). A value of $P < 0.05$ was considered significant. A linear mixed-effects model was also used, allowing for different variances within the levels of a group factor. In statistics, the term "covariance components models" is often used, alluding to the fact that in linear mixed-effects models, we may decompose the covariance into components attributable to within-groups vs. between-groups effects. This was useful for better insight into how the two groups behaved before and after the dive, and what the differences were between the groups. Data are presented as mean and 95% confidence intervals (CI).

Results

There were no statistical differences between the two groups relating to age, anthropometric data and diving habits. Data related to diving habits were not normally distributed and

are reported as median and range (Table 1). Categorisation of the asthma group and details of their medications are shown in Table 2.

All asthmatic divers were free of respiratory symptoms and without any wheeze on lung auscultation in the period 10 to 60 minutes after the dive. The asthma group had statistically significant reductions in FEV₁, FEV₁/FVC%, FEF₅₀, FEF₇₅ and FEF₂₅₋₇₅ after the dive. In the control group, we found significant increases in VC, FVC and FEV₁, while other parameters did not change after the dive. As these data were normally distributed, they are reported as mean (SD) (Table 3).

Using the linear mixed-effects model, we estimated that the asthma group had lower pre-dive results of VC_{in}, FVC, FEV₁ and PEF, but not significantly when compared to the control group. The asthma group had significantly lower pre-dive values of FEV₁/FVC% ($P < 0.01$), FEF₂₅ ($P < 0.01$), FEF₅₀ ($P < 0.001$), FEF₇₅ ($P < 0.01$) and FEF₂₅₋₇₅ ($P < 0.001$) as compared to the control group. A statistically significant reduction in FEV₁ ($P < 0.01$, Figure 2); FEV₁/FVC% ($P < 0.05$, Figure 3); FEF₂₅ ($P < 0.01$), FEF₅₀ ($P < 0.01$), FEF₇₅ ($P < 0.05$) and FEF₂₅₋₇₅ ($P < 0.001$) were apparent after the dive in the asthma group as compared to the control group.

The control group demonstrated an increase in VC_{in}, FVC and FEV₁ after the dive, although not significantly as compared to the asthma group. The PEF was initially lower, but not significantly, in the asthma group and did not change significantly after the dive in either group ($P > 0.05$).

When considering the individual changes post-dive in the asthma group, one diver with mild intermittent asthma had a reduction in FVC of 26%, in FEV₁ of 22% and PEF of 23%, as well as a reduction in expiratory flow rates at low lung volumes. The other divers in the asthma group had reductions in the range 3–10% of pre-dive values in FVC and FEV₁ as well as in the other respiratory parameters.

Discussion

Significant reductions in expiratory flows at low lung volumes in divers with asthma were observed in this study after a short pool dive. Theoretically, dysfunction of the small airways may cause an underwater asthma attack, as well as air trapping with possible lung barotrauma, but no diver in the asthma group showed any signs or symptoms of bronchoconstriction after the dive. However, one diver with marked decrease in his pulmonary function after the dive was strongly advised against diving in the future. Before participation in the study, this diver had not requested a medical assessment of his fitness to dive. He had logged only 10 air dives, to depths up to 20 metres over one year and had experienced no breathing difficulties during these dives. More importantly, since other divers in the asthma group did not show such dramatic changes, this single diver could

Table 1

Anthropometric data and diving habits of the two groups of divers: asthma group ($n = 22$, 1 female) and control group ($n = 15$, 3 females). Anthropometric data are presented as mean (SD); diving data are presented as median (range)

	Asthma group	Control group
Age (yr)	28.9 (8.2)	30.8 (8.1)
Height (cm)	180.6 (5.7)	179.2 (7.5)
Weight (kg)	82.9 (12.2)	80.1 (13.9)
Diving history (yr)	4 (1–11)	5 (2–10)
Number of dives	80 (10–220)	90 (25–300)

Table 2

Asthma types and medications in the asthma group ($n = 22$); 14 suffered from 'allergic asthma'

Asthma type	No of subjects
Childhood asthma	8
Mild intermittent	10
Mild persistent	4
Medications	
No medication	12
On medication	10
Inhaled short-acting β -2 stimulants	4
Inhaled short- and long-acting β -2 stimulants	2
Inhaled short- and long-acting β -2 stimulants + inhaled corticosteroids	4
No β -2 stimulants used before dive	All

Table 3

Lung volumes and flows, before and after a single pool scuba dive (mean (SD)); the asthma group had statistically significant reductions in FEV₁, FEV₁/FVC% and expiratory flow rates at low lung volumes after the dive; the control group had significant increases in VC, FVC and FEV₁ after the dive (see footnote p. 72 for definitions)

Variable	Asthma group			Control group		
	Pre-dive	Post-dive	P value	Pre-dive	Post-dive	P value
VC _{in} (L)	5.98 (0.89)	5.92 (0.95)	> 0.05	5.99 (1.34)	6.26 (1.35)	< 0.01
FVC (L)	5.93 (0.91)	5.85 (0.92)	> 0.05	5.96 (1.18)	6.22 (1.21)	< 0.01
FEV ₁ (L)	4.44 (0.66)	4.29 (0.77)	< 0.05	5.00 (0.99)	5.17 (1.00)	< 0.05
FEV ₁ /FVC %	75.27 (6.89)	73.10 (6.63)	< 0.001	84.00 (4.95)	83.20 (4.76)	> 0.05
PEF (L s ⁻¹)	10.99 (1.87)	11.04 (2.45)	> 0.05	11.43 (2.56)	11.63 (2.51)	> 0.05
FEF ₂₅ (L s ⁻¹)	7.18 (2.00)	6.81 (2.13)	< 0.01	9.90 (2.66)	10.29 (2.95)	> 0.05
FEF ₅₀ (L s ⁻¹)	4.00 (0.93)	3.69 (1.04)	< 0.001	5.82 (1.51)	6.08 (1.40)	> 0.05
FEF ₇₅ (L s ⁻¹)	1.66 (0.35)	1.52 (0.40)	< 0.001	2.48 (1.01)	2.52 (0.93)	> 0.05
FEF ₂₅₋₇₅ (L s ⁻¹)	3.53 (0.82)	3.26 (0.88)	< 0.001	5.09 (1.40)	5.24 (1.49)	> 0.05

have weighted to a small degree the differences observed between the asthma and control groups.

Previous studies have indicated acute as well as long-term changes in pulmonary function amongst saturation and professional divers who had used air or oxygen as the breathing gas.¹⁵ Our findings fit some others, which found that divers had larger lung volumes than a standard reference population and that small airways function might be disturbed in healthy divers after compressed air dives.^{16,17} The long-term changes included a reduction in expiratory flows at low lung volumes and a greater increase in FVC than in FEV₁, with an associated reduction in the FEV₁/FVC ratio.^{18,19}

It has been speculated that diving itself might induce bronchial hyperresponsiveness by affecting small airways function due to breathing cold, dense gas, which increases airway resistance. The work of breathing is further increased during immersion by the increase in intrathoracic blood volume and consequent small airways closure.²⁰ In a cross-sectional study of 28 divers and a control group of 31, a higher prevalence of bronchial hyperresponsiveness to histamine among divers than in non-diving matched controls has been reported.²¹ In participants with asymptomatic respiratory atopy, diving caused a decrease in airway conductivity.²² It was also found that scuba diving was associated with the development of early airway hyperresponsiveness in atopic subjects.^{23,24}

In another recent study, it was demonstrated that compressed air breathing via a scuba regulator on land in laboratory conditions increased the severity of exercise-induced bronchoconstriction (EIB) in susceptible individuals. These results have implications for those individuals with EIB wishing to dive.²⁵

A mechanism that would explain some of the changes seen post-dive in the asthma group might be an inflammatory reaction based on pre-existing airway hyperresponsiveness.

Raised exhaled NO and endothelin 1 plasma concentrations, even after short hyperbaric air exposures commonly practised by recreational divers, provide some evidence that an inflammatory reaction and/or repeated oxidative stress or capillary stress failure might cause small airways dysfunction, which needs further investigation.^{26,27} However, as these dives were performed in a chlorinated swimming pool, we could not exclude the possibility that the inhalation of toxic chlorination products might have provoked bronchial hyperresponsiveness. Swimming pool chlorine is reported to increase childhood asthma in industrial countries with attendance at a chlorinated swimming pool being associated with higher risks of asthma, airway inflammation and some respiratory allergies.^{28,29} Contrary to this, a recent, prospective, longitudinal study suggested that swimming does not increase the risk of asthma or allergic symptoms in British children but rather was associated with increased lung function and a lower risk of asthma symptoms, especially among children with pre-existing respiratory conditions.³⁰

According to interviews with divers from the asthma group, none of them noticed that swimming or diving in indoor chlorinated swimming pools provoked any discomfort or triggered asthma attacks. Further studies are needed and dives should be performed in confined open water in order to exclude potential allergic effects from the inhalation of toxic chlorine products. We did not monitor the time needed for the changes in variables to normalise. In future studies, it would be important to perform repeated PFTs at several time intervals after the dives and assess the dynamics of possible changes in variables.

The PFT changes observed in this study were completely different both within and between the two groups. While the asthma group exhibited a reduction in dynamic parameters, the control group showed a slight increase in static parameters, without any impairment of dynamic ones. The increases in VC and FVC in the control group post-dive might be the result of increased muscle strength due to repetitive resistive breathing during the diving activity.

The increase in FEV₁ is less easy to explain. It might be that the increase in VC and total lung volume, with a resultant increase in large airways diameters could compensate for the expected increase in airway resistance. This might increase FEV₁ when compared to pre-dive values, in healthy, well-trained divers.

PEF was initially lower, although not significantly so, in the asthma group and did not change significantly after the dive in either of the groups. This questions the utility of this measure in estimating the status of the respiratory system after a dive. Those parameters that it would be useful to follow up in order to reveal who might be prone to an asthma attack during a dive are not clear. One might well speculate whether such a brief 'diving exercise test' as performed in this study might usefully be included in a 'fitness-to-dive' assessment protocol to assist in improving the estimate of risks of diving in candidates who have asthma.

Some authors do not support the idea that asthma-provocation tests, or exercise on a treadmill are particularly useful for assessing the fitness to dive of people with asthma.²¹ More recently, some dive physicians have begun to take a more liberal, informed consent approach in assessing previous or mild asthmatics for diving. It seems reasonable that decisions must be made on an individual basis and involve the patient through informed, shared decision making. We would agree with Dr Neuman's opinion that: "In contrast to many earlier recommendations, the importance of an open mind and individual assessment are becoming increasingly recognised."³

There is no 'absolute truth' here. However, more research is necessary and suggested further investigations would be to test divers with asthma in different diving conditions, adding a depth component first in controlled, confined waters, and then adding both depth and temperature variables in controlled open-water dives. This is achievable within the DAN Europe model of participated research and the DAN-UWATEC Diving Safety Laboratory that creates and maintains permanent laboratory research on the safety of recreational diving. We intend to replicate the dives in the deep pools that are available in Belgium and France, followed by exposure in lake-diving conditions.

Conclusions

A single pool scuba dive to 5 metres' depth may impair small airways function in divers with asthma. All divers in the study were free of symptoms after the dive. In one diver in the asthma group, we found reductions of 22–26% in FVC, FEV₁ and PEF of the pre-dive values, and he was advised against further diving. In the other divers in the asthma group, reductions in these parameters were 3–10% of the pre-dive values. More research is necessary in deeper pools and in controlled open-water conditions, adding depth and temperature variables in such controlled dives.

Acknowledgements

We would like to thank diving instructors Sinisa Karalic and Aleksandra Karalic (Nautilus Diving Club, Belgrade), for providing diving equipment and acting as safety divers during the tests. We also thank diving instructors Zoran Rubinjoni and Bratislav Markovic (Amfora Diving Club, Belgrade), for providing us with access to an appropriate swimming pool.

References

- 1 Weaver LK, Churchill SK, Hegewald MJ, Jensen RL, Crapo RO. Prevalence of airway obstruction in recreational SCUBA divers. *Wilderness Environ Med.* 2009;20:125-8.
- 2 Elliott DH, editor. *Are asthmatics fit to dive?* UHMS Publication number 06-21-95. Bethesda: Undersea and Hyperbaric Medical Society; 1996. 81 pages.
- 3 Neuman TS, Bove AA, O'Connor RD, Kelsen SG. Asthma and diving. *Ann Allergy.* 1994;73:344-50.
- 4 Farrell PJS, Glanvill P. Diving practices of scuba divers with asthma. *Brit Med J.* 1990;300:166.
- 5 McAniff JJ. *United States Underwater Diving Fatality Statistics, 1989.* University of Rhode Island, National Underwater Accident Data Center; 1991. 1989 Report No.: URI-SSR-91-22.
- 6 Neuman T. Pulmonary Considerations I, In: Linaweaver PG, Vorosmarti J, editors. *Fitness to Dive.* Thirty-fourth Undersea and Hyperbaric Medical Society Workshop. Bethesda: UHMS; 1987.
- 7 Divers Alert Network. *1992 Report on Diving Accidents & Fatalities.* Durham, NC: Divers Alert Network; 1994. p. 50-67.
- 8 Divers Alert Network. *Annual Diving Report – 2008 Edition.* Durham, NC: Divers Alert Network; 2008. p. 55-72.
- 9 Edmonds C, Walker D. Scuba diving fatalities in Australia and New Zealand. The human factor. *SPUMS Journal.* 1989;19:94-104.
- 10 Tetzlaff K, Muth CM. Demographics and respiratory illness prevalence of sport scuba divers. *Int J Sports Med.* 2005;26:607-10
- 11 Naureckas ET, Solway J. Mild asthma. *N Engl J Med.* 2001;345:1257-62.
- 12 United Kingdom Sport Medical Diving Committee. Medical standards. Available from: <http://www.uksdmc.co.uk>.
- 13 Cotes JE, Chinn DJ, Quanjer PH, Roca J, Yernault JC. *Standardization of the measurement of transfer factor (diffusing capacity).* Report Working Party on Standardization of Lung Function Tests, European Community for Steel and Coal. Official Statement of the European Respiratory Society. *Eur Respir J.* 1993;6(Suppl 16):41-52.
- 14 Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. Standardisation of Spirometry. Series "ATS/ERS task force: Standardisation of lung function testing". Brusasco V, Crapo R, Viegi G, editors. *Eur Respir J.* 2005;26:319-38.
- 15 Crosbie WA, Reed JW, Clarke MC. Functional characteristics of the large lungs found in commercial divers. *J Appl Physiol.* 1979;46:639-45.
- 16 Skogstad M, Thorsen E, Haldorsen T, Melbostad E, Tynes T, Westrum B. Divers' pulmonary function after open-sea bounce dives to 10 and 50 meters. *Undersea Hyperb Med.* 1996;23:71-5.

- 17 Tetzlaff K, Friege L, Reuter M, Haber J, Mutzbauer T, Neubauer B. Expiratory flow limitation in compressed air divers and oxygen divers. *Eur Respir J*. 1998;12:895-9.
- 18 Skogstad M, Thorsen E, Haldorsen T. Lung function over 3 years of a professional career. *Occup Environ Med*. 2000;57:390-5.
- 19 Thorsen E, Segadal K, Kambestad B, Gulsvik A. Divers' lung function: small airways disease? *Br J Ind Med*. 1990;47:519-23.
- 20 British Thoracic Society Fitness to Dive Group, Subgroup of the British Thoracic Society Standards of Care Committee. British Thoracic Society guidelines on respiratory aspects of fitness for diving. *Thorax*. 2003;58:3-13.
- 21 Tetzlaff K, Neubauer B, Reuter M, Friege L. Atopy, airway reactivity and compressed air diving in males. *Respiration*. 1998;65:270-4.
- 22 Tetzlaff K, Stashcen CM, Struck N, Mutzbauer TS. Respiratory effects of a single dive to 50 meters in sport divers with asymptomatic respiratory atopy. *Int J Sport Med*. 2001;22(Suppl 2):85-9.
- 23 Koehle M, Lloyd-Smith R, Mc Kenzie D, Taunton J. Asthma and recreational SCUBA diving: a systemic review. *Sports Med*. 2003;33(Suppl 2):109-16.
- 24 Cirillo I, Vizzaccaro A, Crimi E. Airway reactivity and diving in healthy and atopic subjects. *Med Sci Sport Exerc*. 2003;35:1493-8.
- 25 Gotshall RW, Fedorcak LJ, Rasmussen JJ. Severity of exercise-induced bronchoconstriction during compressed-air breathing via scuba. *SPUMS J*. 2004;34:178-82.
- 26 Lemaitre F, Meunier N, Bedu M. Effect of air diving exposure generally encountered by recreational divers: oxydative stress? *Undersea Hyperb Med*. 2002;29:39-49.
- 27 Lund V, Kentala E, Scheinin H, Klossner J, Koskinen P, Jalonen J. Effect of hyperbaric conditions on plasma stress hormone levels and endothelin 1. *Undersea Hyperb Med*. 1999;26:87-92.
- 28 Nickmilder M, Bernard A. Ecological association between childhood asthma and availability of indoor chlorinated swimming pools in Europe. *Occup Environ Med*. 2007;64:37-46.
- 29 Bernard A, Nickmilder M, Voisin C. Outdoor swimming pools and the risks of asthma and allergies during adolescence. *ERJ*. 2008;32:979-88.
- 30 Font-Ribera L, Villanueva CM, Nieuwenhuijsen MJ, Zock JP, Kogevinas M, Henderson M. Swimming pool attendance, asthma, allergies, and lung function in the Avon longitudinal study of parents and children cohort. *Am J Respir Crit Care Med*. 2001;183:582-8.

Submitted: 19 October 2011

Accepted: 08 April 2012

Dragana Ivkovic, MD, is in private medical practice in Belgrade and is Regional Director of DAN Europe Balkans, Belgrade, Serbia.

Marija Markovic, MD, works in the Bureau of Public Health, Belgrade.

Bozica Suzic Todorovic, MD, is in private medical practice in Belgrade.

Costantino Balestra, MD, is Vice-President Research and Education DAN Europe, and Professor in the Environmental and Occupational Physiology Department Pôle Universitaire de Bruxelles Wallonie, Brussels, Belgium.

Alessandro Marroni, MD, is President, CEO and Chief Medical Officer DAN Europe Foundation and President, International Divers Alert Network.

Milos Zarkovic, MD, is a consultant in the Institute of Endocrinology, Diabetes and Metabolism and in the Faculty of Medicine, University of Belgrade, Belgrade, Serbia.

Address for correspondence:

Dragana Ivkovic, MD,

Milovana Marinkovica 17

11040 Belgrade, Serbia

Phone/Fax: +381-(0)11-247-1040

E-mail: <divkovic@beotel.net>