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AN OBSERVATIONAL REGISTER ON DECOMPRESSION ILLNESS DURING RECREATIONAL DIVING ACTIVITY IN MALDIVES

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ABSTRACT

Introduction: The decompression illness (DCI) is an infrequent event and the exact incidence is still unknown and not uniformly established. The aims of our register is a prospective observational study on recreational diving activities.

Materials and methods: A questionnaire to collect data related to diving experience and medical characteristics has been administered. When a DCI occurred, data on the symptoms, physical conditions and of current dive and of the previous 48 hours dives were registered. At the same time, to obtain a case-control group similar data were collected about 5 asymptomatic components of the same diving group.

Results: Among 6^{th} October 2018 to 9^{th} May 2019, 248 subjects has been registered; the total amount of dives by the 248 subjects was 5,331. A significant datum on the analysis of cohort is represented by Body Mass Index (BMI) calculation; the mean BMI of studied subjects is above superior limits of normal values; and particularly significant is the higher value of BMI in males than females.

During the 5,331 dives, 9 DCI events were reported with a rate of 1.6/1,000 dives. Seven of these cases could be classified as type 1 (with cutaneous and muscular involvement) and 2 as type 2 (with neurological symptoms). However, all the events were self-limited and regressed in short time.

DCI events seem to be predominantly present in male and overweight (BMI > 25) subjects. The DCI cases, showed a deeper dive (even if not statistically significant), had the same length and reported higher perception of fatigue than controls.

Conclusions: Our data confirm a low incidence of these events, generally of mild severity. For these cases a local treatment with oxygen normobaric administration, general support, and hydration obtained a complete resolution of symptoms in a short time.

Our register has allowed us to collect also data on population engaged in recreational diving activity. We emphasize the importance of greater medical control in the subjects who perform diving activities, particularly in presence of some cardiovascular risk factors, such as an overweight BMI value.

Key words: Diving–decompression illness–Body Mass Index–cardiovascular risk factors

1 INTRODUCTION

The popularity of recreational diving is steadily increasing and this activity is exposed to a series of risks, and among

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them the most important are due to hyperbarism.

Decompression injuries have traditionally been classified as arterial gas embolism and type 1 and type 2 decompression sickness [1–3]. Type 1 decompression illness is usually characterized by musculoskeletal pain and mild cutaneous symptoms [2]. Common type 1 skin manifestations include itching and mild rashes (distinct from a mottled or marbled discoloration of the skin known as "cutis marmorata" that may presage the development of the more serious type 2 symptoms) [2].

Type 2 manifestations are considered more serious. They are typically divided into three categories: neurologic, inner ear, and cardiopulmonary. Neurologic symptoms include numbness, paresthesia or tingling, muscle weakness, impaired gait, physical cohordination or bladder control, paralysis or change in mental status. Inner ear symptoms include tinnitus, hearing loss, vertigo or dizziness, nausea, vomiting and impaired balance. Cardiopulmonary symptoms, known as the "chokes", include a dry cough, retrosternal pain, dyspnea, and sometimes pink-stained and frothy sputum [1–3].

The protean nature of DCI makes diagnosis difficult [1–3] and since this traditional classification system was not always applied, it has been largely replaced by the inclusive term of "decompression illness" (DCI) [1, 2, 4].

The DCI is an infrequent event (in consideration of numerosity of diving) and the exact incidence of DCI is still unknown and not uniformly established [4] and furthermore, little is still known about diving risk factors and any individual predisposition to DCI [5].

We created a register on recreational diving activities during cruise trips by White Wave Maldives (PVT.LTD.), an Italian diving agency. The aim of this prospective study were to determine the incidence of self-reported symptoms of DCI in relation to number of dives.

2 MATERIALS AND METHODS

At the beginning of each diving cruise (one week or more), a questionnaire to collect data related to diving experience and personal, anthropomorphic and medical characteristics has been administered to all participants in White Wave Maldives activities.

Body Mass Index (BMI) was calculated using the self-reported weight and height as the result of weight (kg)/height2 (m2), and was classified as underweight (<18.49), normal (18.50-24.99), overweight (25-29.99), and obesity (≥30) [6].

The breathing gas was air.

When a DCI occurred, data on the symptoms and physical conditions of the concerned subject was registered, as well as data related to his current dive and those of the previous 48 hours.

At the same time, to obtain a control group, similar data were collected among asymptomatic components of the same diving group.

Individual and diving data of instructor were excluded.

Data were statistically analyzed through X^2 test for the comparison between percentage values and the Student t-test for the comparison between arithmetic means (± standard deviation, SD). A "p" value < 0.05 was considered significant.

3 RESULTS

Among 6^{th} October 2018 to 9^{th} May 2019, 248 subjects has been registered, median age was 53 years (range 10-74 years); 141 were males (56.9%) and 107 females.

The total amount of dives by the 248 people was 5,331.

A significant datum on the analysis of cohort is represented by BMI calculation.

The mean BMI of studied subjects is above superior limits of normal values (< 25); and particularly significant is the higher value of BMI in males in comparison to females (26.01 ± 3.03 vs 22.48 ± 2.89; $p < 0.0001$).

Data related to known pathologies show that this is overall a healthy population with few cardiovascular risk factors.

An interesting datum is the one related to previous DCI (5.2%).

The past recognition of a patent foramen ovale (PFO) (followed by surgical closure) is reported in 7 subjects (in 6 of whom the diagnosis occurred following a DCI event).

Finally, an important datum is related to the medical certification of sporting fitness: this is documented in 48% of subjects. Moreover, the documented certification is present only in 44% of the subjects suffering from significant pathologies (diabetes, hypertension, heart disease, including the closure of the PFO).

Overall, the registered subjects are experienced divers (especially with regard to the male population) with many years of activity (79% > 5 years) and many dives in the curriculum (63% > 200 dives).

The clinical characteristics and those relating to the diving experience of all the registered subjects are reported in Table 1 and Table 2

During the 5,331 dives, 9 DCI events (8 males and 1 female) were reported with a rate of 1.6/1,000 dives.

The symptoms occurred in one case on surfacing from dive, in one case after few hours and in the remaining ones in a period of time ranging from 30 minutes to 3 hours from the end of the dive.

Seven of these cases could be classified as type 1 (with cutaneous and muscular involvement) and 2 as type 2 (with neurological symptoms). Overall, these cases were of slight entity and fleeting duration, 4 of them were not given oxygen, choosing just an attitude of observation of the phenomenon.

For a more complex case of probable vestibular dysbaric syndrome it was necessary to carry out (in the presence of a physician) 100% oxygen therapy with ventimask for few hours. In the subsequent follow-up, a transesophageal echocardiography was performed and showed the presence of a PFO; a magnetic resonance of brain did not show any ischemic alterations.

Analysis of diving profiles of all subjects did not show violation of decompression limits.

However, all the events were self-limited and regressed in times ranging from 20 minutes to the next 36 hours.

It does not seem that the events can be associated with the dive time (2 cases at the first, 3 cases at the second and 4 cases at the last dive of the day), nor with the number of dives from the beginning of the cruise or of the last 48 hours.

Table 3 and Table 4 summarize the main features of these events.

Comparisons of some general data between subjects with a DCI event and the rest of the group are shown in Table 5. Although not reaching statistical significance, DCI events seem to be predominantly present in male and overweight (BMI > 25) subjects.

Comparisons of data relating to diving activity between subjects with a DCI event and control group are shown in Table 6. The DCI cases, showed a deeper dive (even if not statistically significant), had the same dive length and reported higher perception of fatigue than controls.

Table 1. Clinical characteristics of the 248 subjects.

	total n (%)	males n (%)	females n (%)	"p"
n. of subjects	248	141 (59.9)	107 (43.1)	
age (mean ± SD)	50.3 ± 12.5	51.9 ± 12.0	48.2 ± 12.9	
BMI				
(mean ± SD)	24.49 ± 3.44	26.01 ± 3.03	22.48 ± 2.89	< 0.0001
underweight (< 18.49)	6 (2.4)	0	6 (5.6)	< 0.02
normal (18.50-24.99)	136 (54.8)	55 (39.0)	81 (75.7)	< 0.0001
overweight (25.00-29.99)	106 (42.7)	86 (70.0)	20 (18.7)	< 0.0001
smoke	59 (23.8)	37 (26.2)	22 (20.6)	ns
known diseases				
diabetes	2 (0.8)	2 (1.4)	0	ns
hypertension	14 (5.6)	9 (6.4)	5 (4.7)	ns
ORL problem	4 (1.6)	2 (1.4)	2 (1.9)	ns
chronic ischemic cardiopathy	1 (0.4)	1 0.7)	0	ns
previous diagnosis of PFO	7 (2.8)	2 (1.4)	5 (4.7)	ns
hypercholesterolemia	8 (3.2)	7 (5.0)	1 (0.9)	ns
hypothyroidism	9 (3.6)	0	9 (8.4)	< 0.002
previous neoplasm	2 (0.8)	0	2 (1.9)	ns
anxious/depressive syndrome	3 (1.2)	1 (0.7)	2 (1.9)	ns
previous DCI	13 (5.2)	4 (2.8)	9 (8.4)	ns
fitness certification (< 1 year)	117 (47.7)	66 (46.8)	51 (47.7)	ns

ns: not significant

BMI: Body Mass Index = weight (kg)/height^2 (m^2)
ENT: Ear-Noise-Throat specialist
PFO: patent foramen ovale

Table 2. Diving experience of the 248 subjects.

	total n (%)	males n (%)	females n (%)	"p"
years of diving	18 (7.3)	5 (3.5)	13 (12.2)	<
activity	34 (13.7)	19 (13.5)	15 (14.0)	0.02
≤ 1 year	196 (79.0)	117 (83.0)	79 (73.8)	ns
1-5 years				
> 5 years				
number of dives	14 (5.6)	3 (2.1)	11 (10.3)	<
< 15	29 (11.7)	10 (7.1)	19 (17.7)	0.02
15-50	50 (20.2)	27 (19.2)	23 (21.5)	<
51-200	155 (62.5)	101 (71.6)	54 (50.5)	0.02
> 200				< 0.001

ns: not significant

Table 3. Summary of the clinical features of the 9 DCI events.

n. event	time at onset of symptoms	symptoms	DCI type	duration of symptoms
1	on surfacing from dive	muscolar pain, cutaneous rash, lymphatic swelling	type 1	36 h
2	after 7 h 20'	itching, cutaneous rash	type 1	12 h
3	after 30'	itching, muscolar pain, cutaneous rash	type 1	36 h
4	after 1 h	fleeting paresthesia	type 2	30'
5	after 1 h 10'	itching, cutaneous rash	type 1	2 h 30'
6	after 30'	nausea, dizziness, instability	type 2	30 h
7	after 3 h	itching, cutaneous rash, lymphatic swelling	type 1	30'
8	after 3 h	itching, cutaneous rash	type 1	12 h
9	after 1 h	cutaneous rash	type 1	20'

4 DISCUSSION

The DCI occurs when dissolved gasses (usually nitrogen used in mixed gas diving) exit solution and form bubbles inside the body on depressurization. Proper decompression procedures during diving can help decrease DCI [7].

The DCI is an infrequent event and the exact incidence of DCI is still unknown [4] and, furthermore little is still known about diving risk factors [5].

For recreational diving, rates of DCI ranging from 0.04 to 2.79 per 1,000 dives are reported in the literature (Table 7).

The value we found (1.6/1,000) appears to be higher than reported in the literature, but it must be considered that

Table 4. Summary of the main features of the 9 DCI events.

n. event	time of dive	n. of dives from arrival	n. of dives in the previous 48 hours	average dive lenght in the previous 48 hours (minutes)	average dive depth in the previous 48 hours (meters)
1	15.40	12	4	51.3	28.7
2	15.39	13	6	46.8	32.5
3	15.18	7	5	48.0	33.6
4	11.34	4	4	53.8	38.7
5	7.05	9	1	42.3	48.0
6	10.58	31	6	57.0	39.3
7	12.04	1	1	46.5	33.5
8	15.56	2	2	43.0	34.5
9	7.34	13	6	42.8	31.2

Table 5. Comparison of general data between DCI events vs no-events

	DCI	no-events	"p"
n. cases	9	239	
age (years, mean ± SD)	52.4 ± 9.2	50.3 ± 12.6	ns
sex (M)	8 (88.9%)	132 (55.2%)	ns
BMI (mean ± SD)	25.84 ± 3.32	24.44 ± 3.45	ns
BMI > 24.99	6 (66.7%)	100 (41.8%)	ns
diving activity > 5 years	8 (88.9%)	188 (78.7%)	ns
n. of dives > 200	7 (77.8%)	148 (61.9%)	ns
smoke	2 (22.2%)	57 (23.9%)	

ns: not significant

Table 6. Comparison of data relating to dives between DCI events vs case-control group.

	DCI	no-events	"p"
n. cases	9	25	
duration of dive (minutes, mean ± SD)	50.3 ± 6.9	50.2 ± 5.2	ns
depth of dive (meters, mean ± SD)	36.3 ± 12.0	32.4 ± 8.9	ns
water temperature (°C, mean ± SD)	27.2 ± 2.3	28.0 ± 1.7	ns
initial Bar (atm, mean ± SD)	199.6 ± 1.3	199.3 ± 6.4	ns
final Bar (atm, mean ± SD)	60.8 ± 9.5	57.6 ± 17.1	ns
Δ Bar (atm, mean ± SD)	138.8 ± 10.3	141.6 ± 16.8	ns
perception of thermal comfort (cold)	2 (22.2%)	2 (8.0%)	ns
perception of fatigue	4 (44.4%)	1 (4.0%)	< 0.02
alcohol use (< 24 h)	5 (55.5%)	9 (36.0%)	ns
average dive lenght in the previous 48 hours (minutes)	48.6 ± 8.4	48.1 ± 8.1	ns
average dive depth in the previous 48 hours (meters)	34.9 ± 7.5	34.1 ± 7.9	

ns: not significant

Table 7. Incidence rates of DCI/1000 dives reported in the literature.

authors	period	incidence/1000 dives
Gilliam (8)	1989-1990	0.09
Wilmshurst and coll. (9)	1990	0.06
St Leger Dowse and coll. (10)	1990-1994	0.19
Lippmann (11)	1995-2007	0.11
Nakayama and coll. (12)	1996-2001	0.05
Hagberg & Ornhagen (13)	1999	1.52
Ladd and coll. (14)	1999-2000	0.10
Trevett and coll. (15)	1999	0.25
	2000	0.49
Buzzacott and coll. (Canada) (16)	2006-2015	0.04
Buzzacott and coll. (USA) (16)	2006-2015	0.09
Mirasoglu & Aktas (17)	2010	0.02
Ranapurwala and coll. (18)	2010-2011	1.55
Vann and coll. (1)	2011	0.10

these epidemiological studies describe episodes ascertained by medical teams, while our series (recorded by lay personnel present during the cruise activity) are similar to what described by some authors [13,18] which refers to "self-reported" DCI symptoms. It may therefore be that there is an overestimation of the episodes and that minor episodes have also been recorded, confirmed b y t he f act t hat some symptoms regressed spontaneously in a short time without oxygen treatment.

Sometimes only mild symptoms that spontaneously resolved in a short time are reported [18]. These are certainly less serious DCI manifestations, even if they are quite common. In many cases, the itching following a dive is a sign of this type of pathology, but it is almost never reported to the physician. Less common but still associated with DCI type 1 is the obstruction of the lymphatic system, which can result in swelling and localized pain in the tissue surrounding the lymph nodes [2].

However, some mild cases of DCI may not be identified and/or receive treatment [13,18]; in these cases, the decompressive treatment could not indicated, but they must be carefully observed because they can represent the first sign of something more serious. Anyway, the administration of normobaric oxygen is indicated also for these mild presentations [19].

It is however a general rule that the minor form can be both a pathology itself and therefore self-limiting, but also the beginning of a more serious clinical picture. A close observation is therefore necessary in the following hours in any subject [19,20].

The DCI can be influenced by multiple factors such as dive profile and diver's physical characteristics [3]. Numerous studies have shown an association of DCI with age, adiposity, a history of DCI, presence of PFO, fatigue, stren-

uous diving activity, smoking, dehydration, cold exposure after diving, and diving characteristics [3]. Moreover, the incidence of DCI can depends on the length and depth of the dive, and the risk is 2.5 times greater for males than females [7].

The analysis of the cases we observed and the comparison with the control group showed, even if they did not reach statistical significance, a prevalence in male subjects and with overweight characteristics (BMI > 25). This observation is supported by other studies which report higher incidence of DCI rates in men than in women [10,18].

In addition, subjects studied in our cohort with DCI had an average deeper immersion (equal in length) and reported significantly a perception of fatigue.

Moreover, an excess of fat is a DCI predisposing factor as the lipid tissue gets rid slowly of the excess gas. Obesity is associated with both higher bubble grades in doppler ultrasound detection after scuba dives when compared to normal subjects and with an increased risk of DCI [1]. Recently it has been further confirmed that overweight and obesity are associated not only with DCI events, but also with the severity of the disease [21].

The development of diving activity has had an exponential increase in recent years and it is estimated that approximately one million new certifications are released each year [22].

To date, however, there is no specific organization of rescue (especially homogeneous in the localities of greatest diving interest) and there is a need to train and adequately update both doctors and lay/technical divers about the issues of hyperbarism [23]. This is even more necessary and important when this activity is practiced in more disadvantaged geographical or logistical situations to face a possible DCI.

The Consensus Guideline on pre-hospital management of DCI published recently by the Diver's Alert Network (DAN) [20] lists the procedures that must be performed in each case of suspected DCI. In particular, the expert underlined that it is necessary to first evaluate the probability that the reported symptoms are due to DCI or to another disorder related to the dive or to a disorder not determined by diving activity. It is therefore recommended that all divers who become unwell after diving should consult as soon as possible (even by telephone) a diving medicine physician.

In any case the immediate administration of normobaric oxygen is recommended and for this purpose a training of divers in oxygen administration is highly recommended.

A horizontal position is generally encouraged; divers should be kept thermally comfortable, avoiding the dispersion of heat; and oral hydration is recommended with administration of non-caffeinated, nonalcoholic and non-carbonated liquids [20].

Our register has allowed us to collect, in addition to data relating to the DCI, also interesting data on a population engaged in recreational diving activity, almost equally divided between males and females.

Our results are very similar to a recent epidemiological study carried out on a population of Turkish recreational divers [17].

Our data relate to a population of an average age of 50, healthy and with few cardiovascular risk factors, among which the most important is being overweight (average BMI was 24.49). As this is a modifiable risk factor and as according to current guidelines [24] it is not possible to certify suitability for diving activity for BMI > 35, these data suggest constant attention to this aspect of health.

Likewise, particular attention should also be paid to other risk factors such as hypertension, hypercholesterolemia and smoking, which should be carefully evaluated during periodic medical examinations of fitness for diving, with the aim of reducing the risk of accidents during diving activities [24]. In this regard, we found in our cohort a low percentage of subjects with documented medical certification, while many authors underline the need for periodic medical evaluations and emphasize that diver's cardiovascular status is important in the assessment of fitness to dive [26].

Study limitations.

There are some limitations associated with this study.

This is was carried out during diving activities in Maldives cruises, with self-reported symptoms registration.

Data collection and control of possible DCI symptoms were performed by lay personnel with the possibility of an overestimation of the episodes.

The problem of probable under-reporting of DCI has been emphasized, because some divers do not seek care for minor DCI symptoms [13]. It has been reported that there were 1,580 divers who reported symptoms consistent with diving injury, but only 665 sought medical help [18].

Hence, there is a chance that the divers may have over-reported or under-reported the frequency of symptoms.

The logistical situation has made it necessary sometimes to limit treatment to with normobaric oxygen and to monitor the clinical picture, however with excellent outcomes.

Moreover, the low number of DCI events did not allow a significant statistical analysis.

Finally, data of our study represent a part of diving experience: all dives was made in a geographically concentrated area with homogeneous conditions of water and air temperature, visibility, and typical sea conditions.

5 CONCLUSIONS

Recreational scuba diving is a relatively safe sport with a residual risk of DCI events. Our data confirm a low incidence of these events, generally of mild severity, representative of type 1. For these cases a local treatment with oxygen normobaric administration, general support, and hydration obtained a complete resolution of symptoms in a short time.

According to Ranapurwala and coll. [18], we suggest to promote and improve reporting systems for all diving-related injuries and encourage divers to report all symptoms as they occur may also yield better data.

Our register has allowed us to collect also data on population engaged in recreational diving activity. We emphasize the importance of greater medical control in the subjects who perform diving activities, particularly in presence of

some cardiovascular risk factors, such as an overweight BMI value.

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