Incidence and risk factors for symptoms of decompression sickness among male and female dive masters and instructors – a retrospective cohort study

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Hagberg M, Örnhagen H. Incidence and risk factors for symptoms of decompression sickness among male and female dive masters and instructors- a retrospective and cohort study. Undersea and Hyperb Med 2003; 30(2):93-102 - The aim was to determine the incidence of symptoms of decompression sickness (DCS) in dive masters and instructors in relation to number of dives and possible risk factors. Study Design: Retrospective cohort study of dive masters and instructors in Sweden. Study Base: All dive masters and instructors listed with PADI, NAUI and CMAS in Sweden as of January 1st 1999 (2380 divers). Methods: The dive masters and instructors received a validated questionnaire on diving activities and symptoms of DCS in 1999. 1516 men and 226 women answered, i.e. 73 % of the initial study base. Results*:* DCS symptoms were reported by 190 divers. The incidence of DCS symptoms was 1.52 for males and 1.27 for females per 1000 dives. Dive masters, divers not performing decompression-stop dives, divers not practicing advanced diving and divers with a low number of total lifetime dives had a higher proportion ($p<0.05$) of DCS symptoms per 1000 dives. There were no major differences in DCS symptom incidence related to sex, age, asthma, overweight or alcohol abuse in this study.

accidents, decompression, diving, epidemiology, injuries, occupational

INTRODUCTION

Epidemiological studies have shown an increase in decompression sickness (DCS) and fatalities in recreational diving during the last decades [1]. One problem with evaluating trends in decompression sickness is the lack of information on exposure, i.e. the number of dives and number of divers. Another problem is the probable under reporting of decompression sickness because some divers do not seek care for minor DCS symptoms. In the U.K., the incidence of DCS injuries in amateur scuba divers is estimated to be 0.07 per 1000 dives [2].

There has not been a study of the epidemiology of DCS among dive masters and instructors in recreational diving. The incidence of DCS symptoms in relation to the exposure factor number of dives is not known with certainty. The aims of the present study were to determine the incidence of symptoms of decompression sickness in dive masters and instructors in relation to number of dives and to study whether sex, training, diving experience, height, weight and asthma were factors related to the incidence of decompression sickness symptoms.

METHODS

This study was a retrospective cohort study of dive masters and diving instructors in Sweden consisting of all dive masters and diving instructors listed with CMAS (Confederation Mondial des Activitets Subaquatique), NAUI (National Association of Underwater Instructors) and PADI (Professional Association of Diving Instructors) as of January 1st 1999 (2380 professionals). These three organizations represented almost 100 % of all practicing dive masters and instructors in Sweden in 1999. From the three participating organizations, information on age, name and address was collected. Dive masters and instructors were invited to answer a questionnaire about diving activities and health during 1999. The questionnaire was mailed during the spring of 2000. Three postal reminders were sent out. The response rate was 81 % (1939 persons). 179 persons wrote that they did not wish to participate, 15 answered that they worked abroad and could not answer the questionnaire and 4 persons had language difficulties with the questionnaire. The final study group consisted of 1516 men and 226 women, i.e. 73 % of the initial study base.

The age distributions for the male and female responders were similar (Figure 1). The mean age was 32 years for males and 30 years for females. Analysis of the non-responders showed that the age and sex distributions of the non-responders did not differ from those of the responders. There was also no difference in response rates among the three diving organizations.

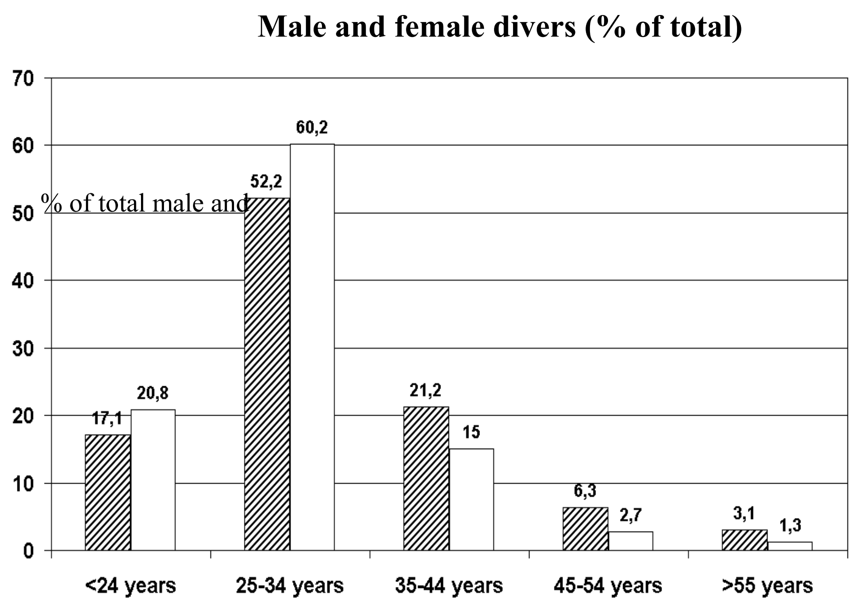

Figure 1. Age distribution for 1516 male (dark bars) and 226 female (white bars) dive masters and instructors

Questionnaire: A validated questionnaire was used to obtain information on different aspects of diving activities and health [3]. The questionnaire was developed by considering the literature on injury epidemiology and diving medicine. Four questions dealt with symptoms of DCS out of a total of 21 questions on different types of injuries. The different types of injuries and their causes were targeted according to ICD-10 (International Classification of Diseases) [4]. A draft version of the questionnaire was sent to 5 diving instructors. They were interviewed whether the questions were clear and whether questions could be misinterpreted. After adjustments (re-writing of questions, new questions, change in layout and order of questions) a Beta 1 version of the questionnaire was developed. A telephone interview was done for each of 30 divers who had answered the Beta 1 questionnaire to check its validity (had the respondent understood the questions the way the investigators intended). Questions with good Kappa values (agreement beyond chance) were left unchanged, and questions with poor Kappa values were changed. A Beta 2 version of the questionnaire was then sent to 6 Swedish experts in diving medicine. After adjustments according to the experts a final version of the questionnaire was established [3]. The questionnaire can be obtained at www.ymk.gu.se/eng/divingmed.pdf.

The questions asked for background data such as height, weight, year of different levels of certification, total number of dives, diving experience and number of dives performed during 1999. There were also questions about injuries. The wording of the injury questions was: Have you had any type of injury/problems during 1999 that have caused medical treatment of any kind or hindered you to work," followed by 21 different types of injuries in a table format. Four questions addressed symptoms of decompression sickness and number of incidents during 1999. The respondent wrote in the number of incidents of each symptom he or she had had during 1999. Cutaneous symptoms were assessed by two questions: one concerning itching after diving, the other rash and skin marbling. The third and fourth questions addressed joint pain, "bends", and neurological symptoms of DCS. There were questions about other injuries, i.e. ankle & wrist pain, cutting injuries, slips and falls etc., that are not addressed in this paper. The questionnaire ended with four questions about the use of nicotine and alcohol (the CAGE questions, [5]). CAGE is excellent in detecting alcohol abuse and dependence [6]. We defined abuse as an affirmative answer to two or more of the four CAGE questions.

Asthma symptoms during the last twelve months were defined as periodical difficulty in breathing or shortness of breath with or without coughing and with or without wheezing. There was also a question asking whether the person had consulted a physician and had been given the diagnosis asthma. Overweight was defined as body mass index (BMI) greater than 25. Because youth may be a risk factor for injuries due to risky behavior and inexperience, young divers were defined as 18-24 years old and "adult" divers as 25 years or older. Questions about advanced diving also were included based on the Divers Alert Network (DAN) definition of "technical dives" [1]. If the diver had practiced at least four of the following eight dive techniques during 1999 he or she was categorized as practicing advanced diving: penetrating wreck diving, cave diving, ice diving, diving deeper than 130 feet/ 40 meters, decompression-stop diving, nitrox diving, trimix diving and rebreather diving.

Statistics: Incidence was computed as number of cases per 1000 open water professional and recreational dives. Difference in incidence was computed as difference in proportions according to Altman [7]. Statistics were computed by using SAS version 8 [8] and confidence interval analysis version 2 [7]. An analysis of risk factors per diver was done as a nested case-control study within the cohort using logistic regression (proc logistic) [8].

RESULTS

The diving activities during 1999 for males and females as dive masters and diving instructors were similar for total working hours, working hours in the water and total number of open water dives (Table 1). Males had more pool dives, more recreational dives and more logged dives compared to females. More males than females had practiced advanced diving in 1999

(Table 2). Overweight and alcohol abuse were more prevalent in males but females had a higher prevalence of physician-diagnosed asthma (Table 3).

Table 1. Diving activities of dive masters and instructors in 1999

		Mean	Median	SD	Q1	Q3
Working hours	Male	170	50	363	3	150
	Female	161	20	307	0	150
In water working hours	Male	55.2	20	154	5	50
	Female	58.9	12	122	0	52
Number of confined water professional dives	Male	28.9	5.5	270	0	20
	Female	21.3	0	80	0	15
Number of open water professional dives	Male	39.7	10	178	0	32
	Female	38.0	8	97	0	26
Number of open water recreational dives	Male	34.4	20	69.8	6	40
	Female	28.0	15	56.0	4	33
Total number of dives (lifetime)	Male	641	300	979	180	644
	Female	459	233	646	134	472

SD= standard deviation.; Q1 = the 25th percentile; Q3 = the 75th percentile

Table 2. Prevalence of different dive profiles of male and female dive masters and instructors in 1999

		Prevalence (%)
Overhead wreck diving	Male	38
	Female	28
Cave diving	Male	22
	Female	21
Nitrox diving	Male	20
	Female	17
Trimix diving	Male	4
	Female	3
Rebreather dives	Male	8
	Female	3
Ice diving	Male	28
	Female	14
Diving deeper than 40 meters	Male	41
	Female	35
Decompression diving	Male	36
	Female	23
Advanced diving (4 of the above 8 profiles)	Male	21
	Female	11

Advanced diving based on Divers Alert Network (DAN) definition of "technical dives" [1]

Table 3. Health characteristics of 1516 male and 226 female dive masters and instructors in 1999

		Prevalence %	PR	95 % CI
Overweight	Male	47.0	3.22	2.34-4.43
	Female	14.6		
Alcohol abuse	Male	8.7	2.81	1.33-5.93
	Female	3.1		
Asthma symptoms	Male	4.42	0.83	0.46-1.51
	Female	5.31		
Asthma diagnosis	Male	4.42	0.59	0.35-0.98
	Female	7.52		

Overweight = BMI ≥ 25; Alcohol abuse = yes to two of four CAGE questions; Asthma symptoms = yes to attacks of dyspnea past 12 months; Asthma diagnosis = physician statement; PR= prevalence ratio (males divided by females), 95 % CI = 95 percent confidence interval

There were 190 divers (171 males and 19 females) who reported DCS symptoms. The differences between males and females in the incidences of different decompression sickness symptoms were small (Table 4). No diver reported more than one incident during 1999.

Table 4. Prevalence and prevalence ratio for decompression sickness symptoms

		Prevalence %	PR	95 % CI
Itching	Male	5.7		
	Female	4.4	1.28	0.68-2.43
Marbling	Male	3.6		
	Female	3.5	1.01	0.49-2.09
Bends	Male	3.5		
	Female	1.8	1.98	0.72-5.41
Neurological symptoms	Male	3.1		
	Female	1.3	2.34	0.73-7.44
Any of the above	Male	11.3		
	Female	8.9	1.34	0.85-2.11

PR= prevalence ratio (males divided by females), 95 % CI = 95 percent confidence interval

The incidence of any DCS symptom in 1999 for the 1516 males was 171 incidents in 112,352 open water dives, i.e. 1.52 DCS incidents per 1000 dives. The corresponding figures for the 226 females were 19 incidents in 14 904 open water dives, corresponding to 1.27 per 1000 dives. The difference in proportions was 0.46 with a 95 % confidence interval of –0.50 to 0.77 (thus, since the confidence interval of the difference included zero, it was “not statistically significant”) (Table 5).

Table 5. Incidence of DCS symptoms in R (risk) and C (comparison) groups per 1000 dives

Risk factor	Risk group (R) (# Cases)	Comparison group (C) (# Cases)	R	C	95 % CI for difference in proportions
Sex	Males (171)	Females (19)	1.52	1.27	-0.50 to 0.77
Age	18-24 years old divers (53)	25+ years "adult" divers (137)	1.45	1.51	-0.50 to 0.44
Skill level – certification	Divemasters (73)	Diving instructors (117)	2.04	1.28	0.27 to 1.32
Skill level – total number of lifetime dives	Total number of dives less than 233 (68)	Total number of dives more than 471 (59)	2.57	0.82	1.15 to 2.46
Skill level – number of years of diving	Less than 6 years of diving (75)	More than 12 years of diving (41)	1.53	1.24	-0.24 to 0.80
Technical dives	At least 4 out of 8 different technical dives (44)	Less than 4 out of 8 different types of technical dives (146)	0.82	1.99	-1.57 to -0.76
Decompression dives	Performed decompression dives 1999 (71)	Had not performed decompression dives in 1999 (119)	1.02	2.06	-1.49 to -0.60
Asthma	Asthma symptoms the last 12 months (12)	No asthma symptoms the last 12 months (178)	1.30	1.51	-0.81 to 0.79
Overweight	BMI ≥ 25 (70)	BMI < 25 (120)	1.43	1.53	-0.53 to 0.35
Alcohol abuse	Yes to at least two out of four CAGE questions (22)	No more than one yes out of four CAGE questions (168)	2.00	1.45	-0.16 to 1.60

95% CI = 95 per cent confidence interval

The incidence of DCS symptoms was of the same magnitude among younger, 18-24 year - old divers compared to 25+-year-"adult" divers (Table 5). Instructors had a lower incidence of DCS symptoms than dive masters. The incidence of DCS symptoms was lower among divers with more than 471 dives (upper quartile among female divers) compared to divers with less than

233 dives (median among women). The incidence of DCS symptoms was lower among divers who performed at least four of eight different types of advanced diving and decompression divers compared to other divers. Experience, measured as number of years in diving, did not affect the incidence of DCS symptoms. Asthma, overweight and alcohol abuse were factors not related to the incidence of DCS symptoms when comparing the incidence rates.

When examining the factors per diver in the nested case-control way by logistic regression, none proved to be a strong risk factor (Table 6). In the nested case-control analysis, the number of dives for each diver is not considered.

Table 6. Logistic regression model for 190 cases of DCS symptoms and 1552 controls

Effect	Risk	Odds ratio	95 % CI
Sex	Male	1.48	0.89-2.47
Alcohol abuse	Yes to two or more of four CAGE questions	1.56	0.96-2.55
Overweight	BMI ≥25	0.74	0.54-1.03
Decompression dives	Performed decompression dives 1999	1.01	0.68-1.50
Advanced diving	Performed at least 4 out of 8 different types of advanced dives 1999	1.24	0.79-1.96
Skill – certification level	Divemaster	0.96	0.68-1.36
Skill – number of dives	More than 471 lifetime dives	0.91	0.63-1.32
Skill – diving years	More than 12 years of diving	0.95	0.63-1.42
Young	Age 18-24	1.34	0.93-1.93

Intercept –2.43 with standard error 0.27. Hosmer Lemeshow test for the lack of fit $p > 0.9$.

DISCUSSION

The incidence of DCS symptoms was high (1.52 and 1.27 per 1000 dives, men and women respectively) compared to other studies. In a retrospective study of scuba decompression sickness and fatalities in the U.S. military community on Okinawa Island, Japan, an annual incidence of 0.134 DCS events per 1000 dives was found [9]. The case definition used was medical records from the recompression chamber and the exposure was the number of scuba air tanks filled at the US facility. During the recovery of TWA flight 800 there were 2 DCS injuries in 3992 scuba dives (incidence= 0.50 per 1000 dives) [10]. In the northern Arabian gulf 35,712 scuba dives in 1993-1995 resulted in 15 DCS injuries (incidence= 0.42 per 1000 dives) [11]. Among the clients of a Caribbean diving tour operator the incidence of DCS was 0.09 per 1000 dives [12]. The most likely reason for the three to tenfold discrepancy between the incidence in our study and the cited studies is that in our study the DCS symptoms were self-reported in a questionnaire. The other studies used information based on recompression chamber treatments.

We do not have information on how many of our dive masters and instructors had recompression treatment but it has to be a small number since the total number of treatment cases for scuba divers in Sweden was 23 in 1999. We have discussed our results with dive masters and instructors, and told that symptoms of DCS that are interpreted as mild are common and that it is not unusual to "wait and see" whether there is a spontaneous recovery. Even DCS symptoms such as numbness and tingling may not always initiate documented therapy. Treatment by breathing 100% oxygen at one atmosphere by demand control regulator may occur frequently without any medical record of the treatment since oxygen is readily available at diving schools, on diving expeditions and at dive sites.

In 2000 Brubakk and Eftedahl [13] presented data from questionnaires returned from different categories of divers in Norway (740 recreational divers, 365 professional air divers and 112 saturation divers). They found that 19% of the recreational divers, 50% of the professional air divers and 63% of the saturation divers had experienced symptoms of DCS that never were treated or reported. A majority of these symptoms were interpreted as CNS related. This tells us that there might be a significant number of divers who never get treatment because the symptoms disappear or who misinterpret their symptoms as not being caused by DCS.

Prompt medical evaluation of DCS symptoms is necessary since early treatment in definite and especially in type 2 DCS prevents future disability. Our study with a low number of hyperbaric chamber contacts in relation to the incidence of DCS symptoms shows that there is still a need to encourage divers to make medical consultations when symptoms of DCS occurs.

Education and training seemed to reduce the incidence of DCS symptoms per 1000 dives since dives done by instructors, advanced divers and experienced divers led to a lower proportion of DCS symptoms. This could be the result of diving training leading to increased safety behavior but could also be due to a healthy diver selection. Safety is a top priority in the three organizations that participated in this study and the higher the qualification level, the more safety training and safety awareness is required. Advanced diving requires special education and training, resulting in an increase in safety behavior. Another explanation for the difference in risk for DCS symptoms between dive masters and instructors could be different professional dive profiles. However, there was still a lower incidence of DCS symptoms among advanced divers even when analyzing the data separately for dive masters and instructors. Our interpretation that the incidence of symptoms of DCS is reduced as a result of training and practice is encouraging for the diving industry since this underlines the need for education and training. Our results can also be interpreted as healthy diver selection. Divers who easily perceive DCS symptoms would stop diving and dive masters would not strive to become instructors. Furthermore, they would not attempt decompression-stop dives or other types of technical dives, which are associated with an increased risk of DCS. One argument against this would be that the healthy diver selection would occur before entering dive master training and certification.

Dive masters and instructors are professionals and DCS symptoms occurring in professional practice should be considered occupational injuries. Whether all the DCS symptoms reported should be regarded as injuries can be questioned. However, in a concept model of occupational injury the case definition criterion may be either one of subjective symptoms, physiologic reactions or morphologic change [14].

The prevalence of asthma symptoms was of the same magnitude as in a Swedish population (females 8.0% , males 6.4%) [15]. This is higher than expected since the medical guidelines in Sweden for fitness to dive examinations up to a few years ago recommended doctors not to pass subjects with asthma. Alcohol abuse was of the same magnitude as in a Swedish population sample for both men and women [16].

Limitations of the study. This study was based on a retrospective data collection and analysis raising concerns with recall and selection bias. Recall bias may cause an underestimation of the true incidence rate in the study group. Non-responders may have chosen not to participate due to having no health problems and this could cause an overestimation of the DCS incidence in our study. However, the sex, age and diving organization distributions were similar among participants and non-responders. Whether the reported symptoms of DCS were true DCS symptoms or not cannot be evaluated, but dive masters and instructors have special training in recognizing and differentiating DCS symptoms and we consider this bias small. If the responding population had been amateur scuba divers, the recognition of DCS symptoms may have been poorer. However, it is likely that an incident with DCS symptoms, even if it was mild, would be remembered since dive masters and instructors are well trained to be aware of and identify DCS symptoms. Although we have a fairly large number of divers (1742), we encountered some power problems. Due to the low prevalence of asthma, we only have a power of 27 % to detect a 1.5 relative incidence between asthmatic and non-asthmatic dive masters and instructors. For a twofold relative risk, the power would only be 70 %. The power calculations were made with a cohort size of 1742 with a proportion exposed of 0.05 and an expected incidence of 0.109 in a one-year follow-up.

CONCLUSIONS

We found that divers experience symptoms of DCS more frequently than expected. The incidence of self diagnosed symptoms of DCS was about ten times higher in our population than the documented incidence for recompression treatment of DCS. It did not differ with gender, BMI, age, asthma, and alcohol abuse, while higher level of training, use of advanced diving techniques and frequent diving gave a lower incidence of self diagnosed symptoms of DCS.

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