

- 178: 66-69
- 20 Dunford RG, Vann RD, Gerth WA, Pieper CF, Huggins K, Wachholz C et al. The incidence of venous gas emboli in recreational diving. *Undersea Hyperb Med* 2000; 27 (Suppl): 65
- 21 Wong RM. How safe is pearl diving? *SPUMS J* 1996; 26 (Suppl): 49-60
- 22 Johnston RP, Broome JR, Hunt PD and Benton PJ. Patent foramen ovale and decompression illness in divers. *Lancet* 1996; 348: 1515
- 23 Eckenhoff RG, Olstad CS and Carrod G. Human dose-response relationship for decompression and endogenous bubble formation. *J Appl Physiol* 1990; 69: 914-918
- 24 Wilmshurst P, Walsh K and Morrison L. Transcatheter occlusion of foramen ovale with a button device after neurological decompression illness in professional divers. *Lancet* 1996; 348: 752-753

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## SUBCLINICAL DECOMPRESSION ILLNESS IN RECREATIONAL SCUBA DIVERS

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### Key Words

Decompression illness, recreational diving, research.

### Abstract

This study was designed to determine if there is any evidence suggesting that recreational scuba divers diving within the commonly "accepted norms" (PADI Tables) present any signs of decompression illness. Decompression illness (DCI) is usually only diagnosed when divers have significant symptoms, such as paralysis, paraesthesia, severe rash, pruritus, etc., which lead them to consult a doctor. Divers usually neglect fatigue, headache, itchiness, and slight disturbances of gait which can be the first symptoms of DCI. This study attempted to determine if any of these sub-clinical forms of DCI were present after normal dives and their incidence. The study was performed in the Republic of

Maldives over a 2 month period on a group of 28 divers and a control group of 9 non-divers. A questionnaire was submitted to every volunteer at the beginning and at the end of his/her holiday. A neurological test (Sharpened Romberg) and an otological exam were also performed on those two occasions. The analysis of the results showed no difference in the prevalence of symptoms before and after the dives in either of the 2 groups. This suggests that there is no incidence of subclinical DCI among the population tested. It is important to emphasise that this study was conducted on a limited number of cases and that all the divers tested were usually diving in warm, shallow waters, well within the limits of the PADI decompression tables and that therefore they did not expose themselves to significant risk of DCI. It would be interesting to carry this study on further on a group of divers who expose themselves more risk of DCI by diving closer to the PADI no-decompression limits. Therefore the author is planning to continue this study in collaboration with dive centres diving on wrecks.

### Introduction

The objective of this study is to search for subclinical forms of DCI in recreational divers diving within the limits of the commonly accepted decompression tables/computers.

### Definition of decompression illness

The mechanisms of DCI are complex and will not be described fully in this text. The basic principle is supersaturation of tissues by a gas with the appearance of gas bubbles in the tissues. This can cause severe symptoms, such as joint pain, paraesthesiae, paralysis and coma. However it may only cause common and unspecific symptoms such as: fatigue, headache, weakness, dizziness, cognition impairment, itching etc.

### Is decompression illness under diagnosed?

The diagnosis of DCI is usually made when a patient presents to a Hyperbaric unit.<sup>1</sup> As many divers who present for treatment put up with their symptoms for many hours,<sup>2</sup> and often for days, there must be a pool of people who recover spontaneously before they realise that they have DCI.<sup>3,4</sup> Mild cases of DCI probably remain undiagnosed most of the time because the diver hardly notices anything wrong. The subtle non-specific symptoms are not disturbing enough to seek medical attention.

Therefore we must ask ourselves "Is DCI widely under diagnosed?"

Ultra-sound studies show that many decompressions are accompanied by detectable bubbles in the circulation without symptoms.<sup>5</sup> When should we start to use the term

DCI? When bubbles are present? When MRI or other imaging techniques show changes? When the patient presents vague, unexplained symptoms such as headache or fatigue? Or simply when the patient presents with severe symptoms? As DCI incidence appears to have a normal distribution,<sup>6</sup> none of these suggestions is an acceptable end point. Instead of trying to establish a cut off point for the diagnosis of DCI we decided, in this study, to analyse the change in prevalence of symptoms before and after a series of dives.

The list of symptoms that were enquired about corresponds to those used to track improvements in the clinical condition of patients with DCI after treatment.<sup>7</sup>

### Possible causes of under diagnosis of DCI

The main possible causes of under diagnosing of DCI among recreational divers include:

Most symptoms of DCI are non-specific to DCI and can easily be attributed to another cause. This applies particularly on holidays when divers participate in various activities they are not accustomed to (Table 1).

One of the more frequent symptoms of DCI is fatigue. A fatigued diver does not have the ability to assess his or her situation correctly and might disregard other neurological symptoms. He or she will first want to sleep it off.

There is a general belief among recreational divers that a diver cannot have a DCI as long as he or she dives within the Tables or within the limits of his or her computer.

There is a general belief that a diver suffering from DCI has made an error or dived unsafely. This alters the diver's image among friends, family, and diving partners.

Most divers know that treatment of DCI involves transfer to a recompression chamber. This involves money, time and can ruin the diver's and his or her family's holidays.

Some divers mistakenly believe that if they are diagnosed with DCI they will never be able to dive again.

### Methods

The study was carried out as the "memoir" required for completion of a 3 year post-graduate sports medicine course at the University of Geneva, Switzerland. As the study was non-invasive and was not asking the volunteers to change their diving habits, it was not submitted to an Ethical Committee.

The study involved collecting data from volunteer guests at the Club Med resort on the island of Farukulofuschi, in the Republic of Maldives. The investigator worked there as a diving doctor performing fitness to dive assessments and treating possible DCI in the on-site recompression chamber.

Data collection started on 1997/4/15 and ended on 1997/6/15. All guests arriving at the resort were informed that a medical study was being carried out, that it was voluntary and that it only required two 15 minutes sessions of their time.

Those interested received an invitation to attend the first session the next morning. At this meeting they were informed about the purpose of the study and were given an "Information leaflet and informed consent form".

Volunteers were between the ages of 18 and 60, had not dived in the last 3 weeks (a check out dive to 7 m max was allowed), were able to read English or French fluently and signed the consent/disclaimer. They had to have no history of neurological disease, concussion, loss of consciousness, paralysis, loss of sensitivity, inner ear disease, or dizziness. Volunteers wishing to participate then signed the form and received an "Initial Questionnaire" (Figure 1).

After completing the initial questionnaire the volunteers had their ears examined by the investigator. Then the sharpened Romberg test (SRT) was explained and demonstrated once by the investigator before the volunteer attempted it up to four attempts.<sup>8,9</sup>

Two important factors, alcohol and seasickness, can effect the SRT. By doing the test in the morning the volunteers were probably sober and had not been on a boat

**TABLE 1**

### COMMON DIFFERENTIAL DIAGNOSES FOR DCI SYMPTOMS AMONG RECREATIONAL DIVERS

Fatigue	Difficult dive, long boat trip, late partying, lack of sleep
Itchiness	Dry skin, salt water, sunburn, lotions, marine animals
Numbness	Cold water immersion, tight wetsuit, marine animals
Joint pain	Other unusual activities done during holidays (tennis, windsurfing, etc)
Dizziness and unsteady gait	Seasickness, dehydration, alcohol consumption

**Do you have right now (or within the last half hour) any of the following symptoms:**  
*If there is a word you do not understand, please ask the doctor to explain it to you.*

**Important:** If you answer “Slight” or “Severe” to a symptom, you must give an answer in the column “Probable cause according to you”. If there seems no obvious cause then tick “I don’t know”.

\*\*\*Please consider carefully \*\*\*

	<u>No</u>	<u>Slight</u>	<u>Severe</u>	<u>Probable cause according to you</u>	
				<i>I don't know</i>	<i>I am quite sure it is due to:</i>
Pains:					
Pain in a joint	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Pain in ear	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Headache	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Sore throat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Pain when passing urine (in last 12 hours)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Other pain (Where: .....)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Fatigue, lethargic	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Muscular weakness	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Nasal congestion	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Tingling sensation in arm or leg	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Diarrhea (in the last 12 hours)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Vomiting (in the last 12 hours)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Numbness in arm or leg	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Dizzy or unsteady when walking	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Itchiness	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Feeling of having water in ear	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Hearing loss	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....
Other problem: .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	.....

**Figure 1.** Part of the questionnaire used for the initial and final interviews.

in the last few hours. As all guests arrive by boat from the airport, and are usually tired from the trip, the initial assessment was not performed on the day of arrival.

Finally each volunteer was given an appointment on the morning of the day before his or her departure. If he or she stopped diving for more than 24 hours the final assessment was to be done not more than 24 hours after the last dive.

At the final appointment the volunteers filled in the “Final Questionnaire” which is similar to the initial one but also inquired about the dives done since the initial assessment: dates, depth, duration, non-respect of tables or computer (which would imply the exclusion of the study), etc. They again attempted the SRT and had their ears examined.

**Bias**

We assumed that there was no difference between the population who agreed to participate in the study and those who did not.

As this was a non-randomised and non-blinded study, the volunteer obviously knew whether he/she had dived or not. This might not affect the initial assessment; it might however influence the answers to the final questionnaire and perhaps even the outcome of the final SRT. A volunteer who has dived might be more inclined to give false positive answers to symptoms than the non-diver. In order to minimise this bias, non-DCI symptoms were included in the questionnaire. However this precaution is not totally foolproof, as many divers know what the symptoms of DCI are and therefore might be more likely to give false positives only on the DCI related symptoms. Only a blinded study would totally avoid this bias.

The investigator did not have the results of the initial SRT and otological exam available when he performed the final examination.

**Results**

Among the 56 volunteers participating in the initial evaluation (Table 2): 28 dived and returned for the final

**TABLE 2**  
**POPULATION DISTRIBUTION**

	<b>Study Group</b>	<b>Control Group</b>	<b>Unfinished Group</b>
Number of cases	28	9	13
Males 17	3	6	
Females	11	6	7
Male/Female [% ratio]	61/39	33/67	46/54
Age [Average]	37	40	32
Have dived before	71%	33%	46%
Number of dives during study (average)	6.4	0	?
Total dives at end of study (average)	27	0.75	?

assessment (Study group), 9 did not dive and returned for the final assessment (Control group), 13 did not return for the final assessment (Unfinished group) and 6 volunteers, two female and four male, were excluded from the study because of previous medical history.

#### **Initial data**

The data gathered from the questionnaire was analyzed in the following way: First all the DCI compatible symptoms were considered. Table 3 gives the number of cases who present with 0,1,2,3,4, and 5 symptoms.

#### **Comments**

One can see that in Table 3 there were more DCI compatible symptoms on arrival (before the dives) than on departure. This was mainly due to the presence of a great number of "fatigued" volunteers. Even though only a few gave an explanation for their fatigue it seems obvious in that setting that many were fatigued on arrival due to their long trip they had the previous day. Due to those special circumstances we decided to exclude all "fatigue" symptoms from the analysis.

In the assessment forms the volunteers had the opportunity to attribute a cause to the various symptoms. Obviously the volunteer's judgment of the origin of a symptom may be wrong. However in this population of volunteers participating in all sorts of sports (besides diving) it was necessary to give them a chance to give a rational explanation (if there is one) for their symptoms. (Table 4). This led to the exclusion of a number of DCI compatible symptoms.

It must be noted that the same three volunteers in the study group who failed the SRT on the initial assessment also failed in the final assessment. No explanation was given by the volunteers (no relevant medical history) therefore those cases were not excluded.

Any evidence of middle ear barotraumas, either otological findings on examination or sensation of water in the ear expressed by the volunteer led to the exclusion of his answer for "Dizziness" and "Hearing loss" as well as the exclusion of the Romberg test result. The reason being that it is known that middle ear barotrauma can be associated with transient inner ear dysfunction responsible of dizziness, hearing loss and a failed sharpened Romberg test.

**TABLE 3**  
**NUMBER OF CASES WITH DCI "COMPATIBLE" SYMPTOMS**  
**(a failed SRT is considered a symptom)**

<b>Total of</b>	<b>Study Group</b>		<b>Control Group</b>	
	<b>On arrival</b>	<b>On Departure</b>	<b>On Arrival</b>	<b>On Departure</b>
0 DCI symptoms	10	11	1	4
1 DCI symptoms	12	10	3	3
2 DCI symptoms	4	5	2	0
3 DCI symptoms	1	1	2	1
4 DCI symptoms	1	1	0	1
5 DCI symptoms	0	0	1	0

**TABLE 4**  
**PREVALENCE OF DCI “COMPATIBLE” SYMPTOMS ON ARRIVAL AND DEPARTURE**

<b>Study Group (28 volunteers)</b>				
<b>Symptom</b>	<b>Assessed on</b>	<b>Number of cases (prevalence)</b>		<b>Probable cause of symptom</b>
Pain in a joint	Arrival	2	(7%)	1 Chronic post ski trauma (symptom not present at departure)
	Departure	3	(11%)	1 Chronic, 2 due to windsurfer trauma
Headache	Arrival	2	(7%)	1 “Flu”
	Departure:	0	(0)	
Fatigue	Arrival	11	(39%)	See comment in text
	Departure	6	(21%)	See comment in text
Muscular weakness	Arrival	1	(4%)	
	Departure	0	(0)	
Tingling sensation in limb	Arrival	0	(0)	1 Known spinal problem
	Departure	1	(4%)	
Numbness in arm or leg	Arrival	1	(4%)	1 Post skiing trauma
	Departure	1	(4%)	1 Post skiing trauma
Dizziness or unsteady gait	Arrival	5	(18%)	1 “Stress + personal problems”
	Departure	5	(18%)	1 Severe middle ear barotrauma
Itchiness	Arrival	2	(7%)	1 Insect bite
	Departure	3	(11%)	2 Insect bites
Hearing loss	Arrival:	0	(0)	1 Middle ear barotrauma
	Departure	2	(7%)	
Failed SRT	Arrival	3	(11%)	3 Middle ear barotrauma with probable transient inner ear dysfunction (see comment further in text)
	Departure	6	(21%)	

### Corrected data

Considering the previous comments, the data was corrected to exclude DCI symptoms and signs *probably due to other causes*. (Table 5)

### Discussion and conclusions

Recruiting volunteers among the guests on a holiday resort is a challenging task. When the study was presented to arriving guests, many did show an interest. Unfortunately a large number of them got involved in other activities and did not show up the next day for the initial assessment.

Among the volunteers the study stimulated a lot of interest, they asked many questions and some were eager to visit the decompression chamber.

The results of the data gathered show no change in the prevalence of DCI compatible symptoms before and after the dives, this both in the uncorrected and the corrected data. As mentioned previously, no attempt to set a cut off point (for example number of symptoms) to establish the diagnosis of DCI was made. We preferred to observe symptom prevalence. As the prevalence is the same before and after the dives we can suppose that the study also suggests that there was no incidence of subclinical DCI among the population studied.

TABLE 5

**NUMBER OF CASES WITH DCI "COMPATIBLE" SYMPTOMS UNEXPLAINED BY OTHER EVENTS  
(an unexplained failed SRT is considered a symptom)**

Total of	Study Group		Control Group	
	On arrival	On Departure	On Arrival	On Departure
0 DCI symptoms	20	21	3	4
1 DCI symptoms	6	4	2	3
2 DCI symptoms	1	2	3	1
3 DCI symptoms	1	0	0	0
4 DCI symptoms	0	0	1	1

Unfortunately we cannot generalise those results to all recreational diving for two reasons.

Firstly, the study was carried out on a limited number of cases. Secondly, the diving in the Maldives is usually shallow, the best coral being between 2 and 15 m, therefore most divers did not come close to the maximum bottom time permitted by the decompression tables or computers.

The incidence of subclinical DCI might be higher among recreational divers diving on wrecks, which are often deeper and divers usually spend most of their bottom time at the maximum depth of the dive.

In this study we assessed volunteers at the beginning and at the end of their holidays, thus every diver would accumulate dives during that period making the study more sensitive for showing evidence of sub-clinical DCI. We assumed that as long as the volunteer dived at least once every 24 hours the risk would be cumulative. However had such an evidence have been found, the calculation of an incidence per dive would have been very difficult. Furthermore the validation of the data with such a small control group would have been difficult. The numbers of factors that intervene during an entire holiday are huge.

An easier but probably less sensitive approach would be to assess the volunteers before a dive and then again 6 hours after. For such a scenario, the best control group would be volunteers who went on the same boat and snorkeled while the study group dived (therefore also being exposed to the boat, sun, water, food, etc). This could be carried out on one-day dive/snorkel boats.

The author is considering continuing this study in collaboration with various dive centres diving closer to the table limits (such as diving on wrecks). Any organisation interested in this collaboration may contact the author.

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#### References

- 1 Moon R. Assessment of patients with decompression illness. *SPUMS J* 1998; 28 (1): 23-29
- 2 Richardson K, Mitchell S, Davis M and Richards M. Decompression illness in New Zealand divers: the 1996 experience. *SPUMS J* 1998; 28 (1): 50-55
- 3 Francis J. Decompression illness in sports divers: the UK experience. *SPUMS J* 1998; 28 (1): 42-45
- 4 Gardner M, Forbes C and Mitchell S. One hundred divers with DCI treated in New Zealand in 1995. *SPUMS J* 1996; 26 (4) 222-225
- 5 Walker M. Doppler bubble detection after hyperbaric exposure. *SPUMS J* 1996; 26 (3): 146-154
- 6 Doolette D. Uncertainties in predicting decompression illness. *SPUMS J* 2000; 30 (1): 31-36
- 7 Mitchell S, Holley T and Gorman D. A new system for scoring severity and measuring recovery in DCI. *SPUMS J* 1998; 28 (2): 84-94
- 8 Fitzgerald B. A review of the sharpened Romberg test in diving medicine. *SPUMS J* 1996; 26 (3): 142-146
- 9 Lee CT. Sharpening the sharpened Romberg. *SPUMS J* 1998; 28 (3): 125-132

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