A RETROSPECTIVE STUDY OF DECOMPRESSION ILLNESS IN RECREATIONAL SCUBA DIVERS AND SCUBA INSTRUCTORS IN QUEENSLAND.

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Condensation

A retrospective examination of all certified recreational scuba divers and scuba instructors treated for symptoms of decompression illness at the Hyperbaric Medicine Unit of Townsville General Hospital demonstrated a disproportionate number of instructors treated. No significant differences in diving behaviour were demonstrated between the two groups studied.

Abstract

A consequence of breathing air under pressure is the risk of developing decompression illness (DCI) secondary to the increased partial pressures of nitrogen. Scuba instructors are subject to repeated and large changes of pressure due to the multiple ascents and descents required for student training. It is postulated that scuba instructors are at a greater risk of developing DCI than the recreational diving population as a whole.

This study examined the recreational diving community of Queensland, Australia, including the Great Barrier Reef, with Papua New Guinea and the islands of the Southwest Pacific. The incidence of DCI and the diving behaviour of scuba instructors were compared with those of the recreational diving community to determine if they were significantly different.

Introduction

Scuba diving is a sport, like many others, with inherent risks. One of these risks is the possibility of developing decompression illness (DCI) or "the bends", ostensibly by exceeding limits of depth, bottom time or ascent rate. While scuba diving may not be safer than swimming or lawn bowls,[1] both the perceived and calculated risks of decompression illness in Queensland divers are low. For example, in 1991, 72 divers were treated in the Townsville chamber and the number of dives made under the auspices of the Great Barrier Reef dive tour operators in the same year was reported as 677,767.[2] If we assume that all the divers treated had been with dive tour operators, which they were not, the rate is 0.00010623 or 106 cases per million dives. We have no knowledge of the number of dives performed annually as "private" dives from Queensland, so we can only deduce that the overall rate of decompression illness is lower than that above. A rare illness indeed.

Attention has recently been focussed on diving instructors and whether or not present training practices put them at a higher risk of decompression illness than recreational divers.[3] There has been a disturbing lack of data addressing this issue.[4] We therefore conducted a retrospective study of all scuba divers and scuba diving instructors treated for decompression illness at the Hyperbaric Medicine Unit of Townsville General Hospital between November 1989 and November 1993. The incidence of decompression illness and the diving behaviour of instructors in this population were compared with those of the recreational diving sub-group, to determine whether there were any statistically significant differences.

Materials and Methods

All scuba divers diagnosed and treated for DCI at the Hyperbaric Medicine Unit of Townsville General Hospital between November 1989 and November 1993 were selected for the study (N=251). This included divers from the Great Barrier Reef, Papua New Guinea and the islands of the Southwest Pacific out as far as Fiji and Nauru.

The study was limited to certified recreational divers and instructors, who used conventional scuba equipment and presented with a sole diagnosis of DCI responding to recompression. The exclusion criteria therefore consisted of:

1 Commercial, military and scientific divers
2 Non-certified divers
3 Divers treated for arterial gas embolism, pulmonary barotrauma
4 Divers presenting with multiple symptomatic complaints not alleviated by recompression
5 Divers not using conventional recreational scuba equipment or breathing gases other than compressed air.

Of the 251 divers treated, 187 met the entry criteria and thus formed the study population. Parameters analysed in this group included:

1 Age and sex
2 Frequency of diving during the previous seven days
3 Profile of deepest dive during the previous seven days
4 Whether symptoms developed during a training dive either as an instructor or as a student.

The Student's T-test was used to determine whether statistically significant differences existed between the variables collected for the two groups.

Results

The total number of scuba instructors treated for DCI at the Hyperbaric Medicine Unit of Townsville General Hospital between November 1989 and December 1993 was 38 (20% of the study population). The total number of recreational divers treated for DCI during the same period was 149. Of all scuba divers treated over this time period, 74% (187/251) were recreational divers or diving instructors with a diagnosis of decompression illness, responsive to recompression.

Although the total number of scuba instructors and recreational divers diving the Queensland region during this time interval is unknown, rough calculations can still be made. Using data presented by Dr Jeffrey Wilks,[5] an estimate of the percentage of instructors relative to the total certified diving population of Queensland can be calculated. On the 30th June 1991, there were 636 registered instructors in Queensland. A total of 26,883 new certifications were issued in 1991 by these instructors who represented the four major training agencies in Australia (NASDS, NAUI, PADI, SSI). Thus, a very conservative estimate of the number of instructors as a percentage of the certified diving population is 2%. One can safely assume that this percentage has remained almost constant over the years as the number of certified divers can be expected to increase proportionately with the number of instructors.

If the theoretical propensity to develop DCI is equally distributed among all divers regardless of certification level, the expected incidence in instructors as a percentage of the total number of divers afflicted with DCI should be around the estimated 2%. However, as demonstrated by the data collected from the Townsville General Hospital records, the proportion is 20%; about 10 times higher than expected. Thus the incidence of DCI in the instructor population diving in the Queensland area is disproportionately high.

Statistical analysis in the comparison of discrete variables including sex, age, total number of dives in the last seven days and maximum depth showed no significant differences between the instructor and recreational diver groups (Table 1). These factors cannot therefore be implicated in the causation of the difference.

Table 2 shows that most instructors were afflicted with DCI after a training dive, while this was not found to be true for the recreational divers studied.

Neither the instructors nor the recreational divers treated for DCI showed any gender specific differences with regard to age, number of dives in the previous seven days and maximum depth (Table 3). Males accounted for 54% (81/149) of the recreational divers treated for DCI. In the instructor group, males were in the overwhelming majority, accounting for 76% (29/38) of the group.

Discussion

In spite of uncertainties about the actual figures, it cannot be disputed that diving instructors form a small proportion of the total diving population in Queensland. It has been shown that, in 187 treated cases, a group large

TABLE 1

Variable	38 Instructors	149 Divers	T-test
Male	29 (76%)	81 (54%)	
Female	9 (24%)	68 (46%)	
Mean age in years ± SD	27.0 (±6.0)	27.7 (±7.6)	P = 0.59
Range in years	19-47	15-54	NS
Total number of dives in last 7 days			
Mean number of dives ± SD	6.8 (±5.4)	6.3 (±4.9)	P = 0.62
Range in number of dives	0-21	Range: 1-28	NS
Mean maximum depth ± SD	22.9 (±10.9) m	22.3 (±7.9) m	P = 0.71
Range in m	12-56	6-51	NS
Mean bottom time at maximum depth	35.8 (±18.1) minutes	33.2 (±15.2) minutes	P = 0.41
Range in minutes	8-90	5-115	NS

A comparison of discrete variables, including age, sex, number of dives in last 7 days, maximum depth and bottom time, between instructors and recreational divers treated for decompression illness in the Townsville Hyperbaric Medicine Unit. (SD = Standard Deviation, NS = not significant)

enough for the application of statistical methods, the diving instructors made up 20%. Clearly, disproportionate numbers of Queensland diving instructors develop decompression illness.

If the risk is related to the number of dives made, a comparison can be derived from Dr Jeffrey Wilks' data on dive numbers for 1991.[5] For that year, the best knowledge for numbers of dives in Queensland gave instructor dives to be 54,594 or 8% of the total. Further deductions by Dr Wilks estimated the number of instructor dives to be 127,200 out of an annual total of one million or 12.7%. Again, the instructors are over-represented.

According to a 1992 report of diving injuries published by the Divers Alert Network (DAN),[6] the percentage of US diving instructors developing and reporting DCI has remained at about 10% between 1988 and 1992; half the incidence found in Queensland. The disparity between these two groups is alarming. While dive table use and practice are identical, it is possible that the average Australian instructor diving on the Great Barrier Reef logs more dives than the average instructor in the USA. Weather and water temperatures may not be as limiting on the Reef as around most of the coastal United States.

Part of the requirement for certification by the various agencies offering recreational scuba training is training in the use of dive tables. Despite comprehensive teaching, practical application, knowledge review questions and modular quizzes in the use of dive tables, divers continue to suffer from decompression illness. In many cases the cause is apparent, with the diver, either knowingly or not, violating the limits laid down by the tables or showing a predisposing factor. In other cases, the diver is apparently well within the tables and without any predisposing factor. With the increased application of multilevel diving and the extensive use of dive computers that allow for complex dive profiles to be continuously recalculated during the dive, divers are able to push their dive times even further, perhaps extending their risk of decompression illness.

By comparison, instructors are required by standards, at least in theory, to exhibit conservative diving practices during all teaching sessions. Instructors are expected to be expert in the use of the dive tables, having received comprehensive training in their use, constantly reinforced thereafter by daily application. While engaged in training, instructors are prohibited from exceeding the limits allowed by the tables and increasing their risk of decompression illness. Consequently, one should expect, if anything, a lower than average rate of decompression illness in instructors during training, assuming that some certified divers "push their limits". Even if one dismisses that expectation, how can one account for the disproportion in the number of instructors suffering from DCI despite following conservative diving practices, which do not differ significantly from those of the recreational diving public?

TABLE 2

PRESENTED WITH SYMPTOMS OF DCI AFTER A TRAINING DIVE

	38 Instructors	**149 Divers**
Yes	26 (68%)	27 (18%)
No	12 (32%)	122 (82%)

A comparison of Queensland divers who presented with symptoms of DCI showing the proportions of training dives either as instructor or student.

By nature of their profession, scuba instructors spend a lot of time submerged, training divers in the basic skills necessary for the proper use of scuba. One could argue that, though instructors may show similar diving practices over a seven day period, they dive far more frequently than the recreational diving public. Frequency of diving, however, is not a theoretical predisposing factor in the development of DCI, provided one is diving within the limits set forth by the dive tables. A more likely explanation centres around the skills in which an instructor must participate in order to certify entry level divers. During training, instructors are required to make multiple ascents and descents with their students. The largest training agency in the world, PADI, requires that each student conduct, with direct contact by the instructor (as recommended by the National Scuba Training Committee in 1978), a controlled emergency swimming ascent vertically from a depth of 9 m or less in open water. The octopus assisted vertical ascent must also be performed with the instructor in contact with each student team. If both of these skills are practised as part of open-water dive number 2, as outlined in the PADI Standards and Procedures Manual, the instructor (assuming a maximum open-water class of eight students without use of an assistant) will make a minimum of 13 ascents and descents on a single dive, barring any problems that may arise with students bolting for the surface or losing contact with the group. If conducted as part of open-water dive number 5, the instructor will make a minimum of 9 ascents and descents with the same class of eight students. If, through poor planning, an instructor is landed with two open-water modules from different classes on the same day, the unfortunate instructor has to make 26 ascents and descents! Any of the above numbers may appear excessive.

The data presented in Table 1 show clearly that instructors are not, in any visible way, exceeding the limits of the tables. Their propensity towards development of

TABLE 3

Variable	Male Instructors	Female Instructors	T-test	Male Divers	Female Divers	T-test
Mean age in years (± SD)	27.7 (± 6.7)	25.0 (±3.4)	P = 0.59	28.4 (± 7.1)	26.9(±6.9)	P = 0.59
Range in years	19-47	20-30	NS	18-54	15-50	NS
Total number of dives in last 7 days						
Mean number of dives ±SD	6.5 (±5.1)	7.5 (±6.5)	P = 0.62	6.5 (±5.4)	6.1 (±4.3)	P = 0.62
Range in number of dives	0-21	1-21	NS	1-28	1-20	NS
Mean maximum depth ±SD	22.1 (±10.3) m	25.0(±12.7) m	P = 0.71	21.9 (±7.9) m	22.6(± 7.9) m	P = 0.71
Range in m	12-56	12-44	NS	6-51	10-50	NS
Mean bottom time in minutes at maximum depth ± SD	36.2 (±20.5)	34.6 (±8.0)	P=0.41	34.7 (±11.5)	31.4(±10.6)	P=0.41
Range in minutes	8-90	25-44	NS	5-115	8-55	NS

Demonstration of the absence of gender specific differences in age and diving parameters between both the instructor and recreational diver groups treated for decompression illness in the Townsville Hyperbaric Medicine Unit. (SD = Standard Deviation, NS = not significant.)

DCI may therefore be related to an excessive frequency of multiple ascents and descents, which, by their very nature, do not fall within the dive tables and are not expected by the limited intelligence of the dive computer.

Numerous hypotheses could be offered to explain the disproportionate incidence of DCI in the instructor population of Queensland. In all fairness, the reports given by divers are known often to deviate from the truth or to be limited in accuracy. Yet, with such a large group, it seems unlikely that all are claiming, for reasons unknown, to have adhered to more conservative profiles than the actual dives. Another possibility is that the high incidence of DCI is not related to multiple ascents and descents, but rather to a chronic, long term absorption of nitrogen in tissues that have an extremely long half-time. Thus the instructors may eventually over a long time period, exceed 100% saturation of these tissues and present with decompression illness. No specific studies that have looked at the long term effects of multi-day, multi-dive profiles are known to the authors. It is noted that the dive tables include a caveat, warning divers that the effects of this kind of repetitive exposure to high partial pressures of nitrogen are presently unknown.

It is interesting that the variables investigated in this study, which included age, depth, bottom time and number of dives in the last seven days before presenting with symptoms of DCI, did not differ significantly between the two groups studied. Of note however, was the high incidence of DCI in instructors after training dives. This should not be surprising, as most instructors spend their diving time conducting training dives, i.e. working, and are at risk of DCI during this time. The number of sport divers who sustained DCI during training exercises is considerably smaller, but of concern since according to dive profile, most did not exceed table limits. It is all the more surprising, since one would not expect sport divers with minimal dissolved nitrogen after a short time at shallow depth to develop DCI, even with a rapid ascent. This brings us back to the possibility of multiple ascents and descents being a primary culprit in the aetiology of DCI. Multiple ascents during a so-called single dive, described as "yo-yo" diving,[7] are identified by commercial diving authorities as a predisposing factor in decompression illness. Australian and North Sea regulations for commercial diving consequently forbid the practice. It is listed as a predisposing factor in a respected textbook of diving medicine.[8]

When one examines the gender differences in diving practices among sport divers, the results indicate that there are no notable disparities, except that more male divers are treated for DCI. Similarly, no significant gender differences were found in the instructor population studies. There was however, an overwhelming majority of male instructors.

This study has gone as far as it can. To elucidate reasons for the different rates of decompression illness between instructors and other divers, much more extensive and reliable protocols for gathering information about diving practices are required. This could be accomplished with dive computers containing the capability of down loading collections of detailed dive profiles. It is apparent from our data that no specific factors have emerged to

explain the higher incidence of decompression illness in Queensland diving instructors. However, in the absence of further data, one can speculate or use deductive reasoning. The authors believe that the main difference between the two groups is in diving practice, in that only the instructors regularly perform multiple ascents and descents.

Recreational diving authorities must recognise that diving training procedures put instructors at a higher risk of decompression illness than the general diving population. Further research is needed in this area and recommendations should be developed by the training agencies to avoid continued hardship, disability or, in the extreme, death of the unfortunate diving instructor who is hit by decompression illness.

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Key Words

Ascents, decompression illness, diving industry, safety, recreational diving, reprints.

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The above paper was presented at the Safe Limits Symposium held in Cairns, October 21st to 23rd 1994. It is reprinted by kind permission of the Division of Workplace Health and Safety of the Department of Employment, Vocational Education, Training and Industrial Relations of the Queensland Government, and of the author, from the symposium proceedings pages 52-59..

SAFE LIMITS: ASSESSING THE RISKS

Harry F Oxer

This paper examines “Safe Limits: assessing the risks” with respect to our experience of almost five years of managing dive accidents in Western Australia. The areas we examined include:

Multiple dives on successive days
Rapid ascents
Multiple ascents
Flying after diving or decompression illness

In Western Australia 175 divers presented with possible decompression illness over a four and a half year period. This is in the context of an estimated 40,000 certified divers in this state, though the number of dives carried out is unknown. We see between 30 and 35 cases who are treated each year, of which usually only one is serious. There are few cases of arterial gas embolism.