Decompression sickness and recreational scuba divers

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Objectives: The aim of this study is to clear the status of recreational scuba divers in Japan for promoting safety in recreational diving.

Methods: A five year (from 1996 to 2001) questionnaire survey was performed of Japanese divers at the Osezaki area in Japan. The subjects of this survey included diving instructors as well as recreational divers. Based on the obtained data, the study investigated the theory predicted incidence of decompression sickness (DCS) among Japanese recreational divers.

Results: The average (SD) of the maximum depth for diving was 37.4 (13.1) metres, which was deeper than the recommended depth of recreational diving. The incident rate of nitrogen narcosis (12%) was the most frequent, followed by barotraumas of the ear (11%) and barotraumas of the paranasal sinus (5.6%). The rate of DCS was 1.9 % (60 divers) during investigated period, and that DCS occurred once per 19 011 dives in calculation.

Conclusions: This investigation showed that the status of leisure diving in Japan is still serious, because DCS would be expected to occur once a weekend in Japan. It is speculated that many divers may develop DCS while moving through high altitudes after diving, particularly at the Osezaki diving spot in Japan. Based on the results of this study, it is emphasised that every Japanese leisure diver should take an increasing interest in the safety of diving activity.

In 2001, the population of Japanese recreational scuba divers reached about a million in total, and nearly 80 000 diving certification cards (C cards, diving licences) that permit any recreational divers to enjoy scuba diving, are issued to newly trained divers in Japan.¹ According to information from commercial or other diving related organisations in Japan, the number of active divers in Japan is around 1 000 000. And more than half of these divers are assumed to go diving repeatedly, therefore, the number of divers who enjoy diving several times a year is estimated from 300 000 to 500 000 (unpublished data and Mano³).

Scuba divers dive with a gas filled tank, usually contained air, on their back for underwater respiration to obtain an oxygen supply. Incidentally, divers always have a risk of experiencing decompression sickness (DCS).^{3–4} In Japan, there have been very few investigations into the incidence of DCS among recreational divers. Most of those studies were based on the number of divers seen by a physician in a hospital.^{5–6}

The purpose of this study is to gather information on recreational diving related disorders and to assess safety in terms of depth and the frequency of diving. For this examination, we visited Osezaki, a very popular diving spot in Japan, to question recreational divers directly about the types of diving diseases and conditions, in particular DCS that they have experienced.

METHODS

The subjects of this survey included diving instructors as well as recreational divers. Recreational divers were limited to divers in either of two categories: those possessing a C card and those who had gone diving at least five times.

Data for this study were gathered prospectively from questionnaires. They had been completed through random interviews with divers. These divers were diving at the most famous diving area in Japan, the Osezaki area on Izu peninsula. We have obtained informed consent from the divers.

The data presented were collected over a six year period from June 1996 to October 2001. We performed random interviews twice a year, every June and October. The total number

of interviewing times was 12 during that period. As our survey was based on random interview, and the number of divers at the survey area differed each time, we therefore could not collect an equal number of questionnaires every year.

Data collected included age, sex, years diving, total number of dives, dives per year, experienced maximum diving depth, and diving activity on day of survey.

We categorised the diseases associated with diving into nitrogen narcosis, barotraumas of ear, barotraumas of paranasal sinus, and DCS. These are the most common diseases among recreational divers.^{7–9} However, as there were some divers who often experienced these diseases, or experienced more than one disease at the same time, we inspected the numbers of divers experiencing at least one of any diving disease and calculated the rate of divers who contracted one of any diving disease.

Similarly, concerning DCS, some divers suffered from it repeatedly. Therefore we investigated the number of cases of DCS developed as well as the number of divers who have suffered from DCS.

To obtain the ratio of DCS occurrence among divers at Osezaki, we performed the calculation as follows;

- (1) Counting the number of dives by adding up all the number of experienced dives among reliable responses from divers.
- (2) Calculation of the ratio of one DCS occurrence in proportion to numbers of dives by dividing of the number of DCS developed cases from the number of experienced dives.

RESULTS

Reliable answers were obtained from 3078 divers during the six years of the study, as follows: 499 in 1996, 634 in 1997, 549 in 1998, 499 in 1999, 431 in 2000, and 466 in 2001. More than 60% of the respondents were male, and the average age of the males was 32.0 (SD 8.0). The female respondents averaged 29.5 (7.5) years of age. The respondents had been diving for 5.0 (5.0) years on average. Their maximum diving depth was 37.4 (12.9) metres on average. Divers had dived twice on average on the day they were surveyed. About 72% of the respondents used a diving computer when they dived (table 1).

Table 1 Average annual changes in actual results among recreational divers at Osezaki (1996–2001, n=3078)

Year	Total
Number of divers	3078
Age (y)	
Total	31.1 (7.9)
Male	32.0 (8.0)
Female	29.5 (7.5)
Sex (% female)	37.3
Diving history	
Years diving	5.0 (5.0)
Total number of dives	379.8 (979.3)
Dives per year	59.5 (87.0)
Maximum diving depth (m)	37.4 (12.9)
Activity on day of survey	
Dives	2.0 (0.6)
Divers carrying diving computers (%)	71.8

Table 2 Average annual changes in the numbers and types of diseases associated with diving at Osezaki (1996–2001, n=3078)

Year	Total
Number (rate) of cases of	
Nitrogen narcosis (%)	373 (12.1)
Barotraumas of ear (%)	330 (10.7)
Barotraumas of paranasal sinus (%)	172 (5.6)
DCS (%)	60 (1.9)
Total	935
Divers investigated	3078
Divers experiencing at least one of any diving disease (%)*	711 (23.1)

*Diving diseases include nitrogen narcosis, barotraumas of ear, barotraumas of paranasal sinus, and DCS. DCS, decompression sickness.

With regards to the types and incident rates of diseases associated with diving, nitrogen narcosis (12%) was the most frequent, followed by barotraumas of the ear (11%) and barotraumas of the paranasal sinus (5.6%), respectively. Fifty divers (1.9%) had suffered from DCS (table 2).

The proportion of divers who had suffered from at least one of these diving associated diseases was 23.1% (table 2).

Among the total of 3078 divers in this study, 103 completed the questionnaire twice. Therefore, 2975 divers actually completed the survey. Out of the 2975 divers, 52 people had experienced a total of 60 cases of DCS: 46 divers had experienced DCS only once, five divers twice, and one diver four times.

We obtained the fact that ratio of DCS occurrence among 2975 divers was once in 19 011 dives, based on following calculation: dividing the number of DCS developed cases (60) from the number of experienced dives (1 140 653)—that is, $1\,140\,653/60=19\,010.8$.

DISCUSSION

This study shows that although individual divers are extremely unlikely to experience DCS, it is likely that one case may arise a week in centres such as Osezaki. The average maximum depth of diving was 37.4 (12.9) metres.

DCS is known to occur from the bubbling of supersaturated nitrogen in a body because of inadequate decompression^{3,6} and seems to be caused by imprudent diving actions. We should avoid such actions as they amount to reckless diving. Based on this investigation, divers dived twice a day on average, a rate that could not be considered reckless. According to textbooks of commercial diving instruction organisations, the

recommended depth is shallower than 20 metres for beginner divers, and shallower than 30 metres for more trained recreational divers in Japan.^{10–11} On the other hand, the average maximum depth of diving was 37.4 (12.9) metres, a finding that suggests Japanese recreational divers tend to dive too deeply.

Usually, DCS symptoms are thought to develop within two hours after the diver surfaces.^{4,5} However, we reported that DCS might occur even more than two hours after surfacing, when divers are moving through high altitudes by car.^{12–14} Moving to a higher altitude shortly after diving can cause a development of DCS.^{15–18} To return to Tokyo, Nagano, or Yamaguchi Prefecture, all those who dive on the west coast of Izu peninsula such as Osezaki, have to cross over highlands reaching 400 metres above sea level. And we have also reported the fact that 76%–92 % of divers who dived at Osezaki have to move to a high altitude after diving on the way to home.^{12–13} This fact may strongly suggest a heightened risk of DCS, even if more than two hours have passed after diving. According to a report of DAN Japan, (Divers Alert Network in Japan), which operates a hotline for recreational divers, it showed that 25% of divers suffered from DCS had moved to high altitudes, namely more than 400 metres above sea level, after diving.¹⁴

Based on our consideration of the relation between the incidence of DCS and the number of dives, including cases caused by crossing through high altitudes, DCS occurred at a rate of once every 19 011 dives. Arness reported DCS developed once in 7400 dives.¹⁹ On the other hand, DAN²⁰ and Wilmschurst²¹ reported rates of DCS showed 1/10 000 and 1/20 000, respectively. These reports agree with our findings. Although we did not examine the influences of altitude to DCS in this questionnaire, the relation between crossing through high altitudes and DCS should be more considered for estimation of occurrence of DCS incidences.

To prevent the development of DCS, we propose the use of inhaling oxygen after diving or to wait for some hours before crossing through high altitudes, otherwise, diving with nitrox (a mixed gas containing 30%–40% oxygen and the rest nitrogen) can be helpful if divers use air dive regulation. However, it should be realised that the most important fact is the awareness of every diver with regard to safety in leisure diving.

A limitation of this study was the way of selection of subjects. We performed interviews randomly for any divers who adjusted to our study criteria. So the selected subjects in this study might not truly have been selected randomly. We cannot deny the selection bias in this study.

Finally, we would emphasise that the results of this investigation may contribute valuable educational information for a safety guide to prevent DCS for Japanese recreational divers.

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