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The Editor's Offering

How safe is scuba diving? As Ladd et al point out in our first article, recreational scuba has been variously described as a dangerous high-risk sport to a very safe activity. Whilst the number of fatalities in a given diving community are identifiable with reasonable accuracy, epidemiological studies in sport diving have been hampered by a lack of data on the denominator, that is, the number of divers or the number of dives they undertake. The British Columbia (BC) team argue that it is diving activity that is the most useful parameter to use. They have set out to measure this by counting scuba tank fills throughout BC. It is a remarkable achievement in public relations that two thirds of the fill stations in this huge geographic area co-operated in the project. Whilst their data still only provide us with indicative rates, scuba fatalities in BC appear to be of the same order as drowning rates in Western communities for the population as a whole. This suggests that scuba is no more dangerous than any other water-related activity.

They also report a rate for clinical presentation of decompression illness (DCI) for these cold northern waters (and this is definitely dry suit country) that is the same as that for a tropical live-aboard vessel doing multi-day multiple dive patterns. These two field studies now provide us with some measure of the clinical presentation rate for DCI in sport diving - in the order of I in 10,000 dives. Given the predicted rates of DCI from testing tables and the work of Weathersby, Dick Vann and others on maximum likelihood analysis of decompression procedures, this is a surprisingly low incidence. This again argues for the relative safety of recreational scuba diving (some would say, despite divers' efforts to the contrary). It would be interesting to utilise the health survey method advocated by David Doolette in similar groups of sport divers.[1]

Another aspect of diving safety is reported by Taylor et al. The use of diving-related drugs such as nasal decongestants and anti-motion sickness agents, as well as chronic medication for concomitant medical conditions, is surveyed in two populations of divers in Australia and the USA. Quite high rates of medication use are reported, which parallel a recently published survey of medical conditions in recreational Australian divers by the same group (this paper will be reproduced in the next journal issue).[2] Selfmedication is obviously common amongst divers but may not always be in their best diving safety interests. Not enough is known yet of how many of the commonly used agents might interact with the underwater environment.

Papers from the 2001 ASM continue to trickle in to the editorial office. Our Treasurer, Barbara Trytko, gave two interesting talks at Madang on hyperbaric medicine issues. Following Dr McKay's analysis of the Campbell ventilator in the last issue,[3] she provides a pragmatic insight into some of the general principles and difficulties inherent in ventilating sick patients in a hyperbaric environment. Tile study on blood sugar levels in diabetics will be the topic of her SPUMS Diploma thesis and is therefore reported in abstract form only. The reasons for hypoglycaemia during HBOT are still a matter for conjecture and ongoing research.

This year's ASM guest speaker was Dr Trish Batchelor, whose special interests are travel and altitude medicine. Trish is currently working in Kathmandu, Nepal. Six hours of fact-crammed lectures presented with enthusiasm and a firm intellectual hold on the subject matter confirmed for me the status of travel medicine as a sub-specialty in its own right like diving and hyperbaric medicine. The series of articles by Dr Batchelor that will appear over the next year in the Journal will be an important resource for any medical practitioner who advises travellers, has to manage post-travel illness or is planning to work or vacation abroad themselves. She opens with altitude medicine, the immunecompromised traveller, which includes pregnant women, and an exhaustive list of worldwide resources that members may access.

Hot water immersion has been used for the first aid care of fish spine envenomation for decades to relieve the severe pain of these injuries. The prevailing tenet is that this denatures the heat-labile toxins injected into and beneath the dermis. David Muirhead, a GP in Adelaide, questions this view based on a personal experience. He reviews the literature, which provides no evidence for this assumption, and argues that modern pain theory provides a better explanation for the evanescent relief often obtained.

Some changes to format can be seen in this issue, and further changes will occur in 2003. We are keen to hear from any member of the Society how they would like to see the Journal develop. Diving and hyperbaric medicine are inextricably linked, as has been evident for some years in this publication. Whilst the primary focus will remain diving medicine and physiology, we do wish to see a strong component on hyperbaric medicine, reflecting the rapid growth of this specialty around the Pacific and SE Asia region in recent years.

Mike Davis

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Original articles

The Abacus Project: establishing the risk of recreational scuba death and decompression illness

Gary Ladd, Victor Stepan and Linda Stevens

Key Words
Scuba, recreational diving, deaths, decompression illness, epidemiology

Abstract
In order to establish the relative risk of death and non-fatal decompression illness (DCI) in recreational scuba diving in British Columbia (BC), Canada, a field survey was conducted. For 14 months, every dive shop and charter operator in the province of BC was asked to count the number of scuba tanks that were filled for use in recreational scuba diving. For the same 14-month period, hyperbaric chambers reported the number of BC divers treated for non-fatal DCI and the provincial coroners records were reviewed for scuba fatalities. Over the 14 months that scuba tank fill information was collected, an average of 65% (range: 60-71%) of the fill stations reported. Death and DCI incidence rates were calculated based on the 146,291 fills reported by the participating stations. During this same period there were 3 fatalities and 14 cases of non-fatal DCI. The incidence of recreational scuba death was 0.002% (2.05/100,000 dives). The incidence of non-fatal DCI was 0.010% (9.57/100,000 dives). Results are discussed in light of this being the first time a reasonably reliable measure of diving activity has been achieved in a large geographic area over an extended time period.

Introduction

As a recreational sporting activity, the relative risk of death and non-fatal decompression illness (DCI) in recreational scuba diving is unknown. Sport diving has been variously described as a dangerous, high-risk sport and a very safe activity that has a low mortality risk.[1-4] Calculating the relative risk of sport diving requires accurate information about diving activity, diving fatalities and non-fatal DCI.

Information on the incidence of death and DCI in specific geographic areas or jurisdictions has been available for several years. The Divers Alert Network (DAN) has been compiling and publishing annual reports on recreational diving fatalities and DCI in the United States since 1987.[5] In Australia, Project Stickybeak has documented recreational snorkel and scuba diving fatalities.[6,7] In British Columbia (BC), Canada, the Underwater Council of British Columbia (UCBC) uses information from the provincial coroners service to document recreational dive fatalities.[8,9]

The major impediment in analysing the risk of recreational scuba diving has been the lack of an accurate denominator. Risk estimates have been made using either a diver participation approach (ie. risk/diver) or a diving activity approach (ie. risk/dive). With the diver participation approach the number of divers is used as the denominator while the diving activity approach uses the number of dives as the denominator.

Following up on an inquest into a recreational diving triple fatality, the Abacus Project was created to carry out one of several recommendations by the Provincial Coroners Service to improve dive safety in the province.[10] It was established to investigate the relative risk of death and DCI in recreational scuba diving in the province of BC. The Abacus Project utilized a diving activity approach based on recording recreational scuba diving tanks filled in BC.

Methods

Information was collected on the total number of recreational scuba tanks filled in the province of BC over a 14-month period. This was used as a measure of the number of dives that were done. Each recreational scuba tank fill (fill) was counted as one dive. Information was also collected on the total number of recreational fatalities and cases of DCI for the same period. This information was used to calculate incidence rates.

SURVEY METHOD DEVELOPMENT

The design and preparation of the project took approximately two years and extensive consultation with industry stakeholders (eg. dive medicine specialists, training agencies, charter and dive store operators, Canadian Coast Guard Service, recreational divers, scientific divers). The project required a simple and reliable method of counting fills that every fill station in the province could use. A fill station was defined as any facility that filled scuba tanks with air or other compressed gases used for breathing in recreational scuba diving. This included charter operators, dive shops and other marine services providers (eg. marinas).

Second, the method required a means of reporting the fill information in a timely manner to a central data collection agency in a way that protected the business interests of

the fill stations that reported their information. The Divers Alert Network (DAN) acted as the central collection agency.

Endorsement of the project was sought and received from every certification agency that was operating in the province. ACUC International, IANTD Canada, PADI Canada, SSI Canada and TDI Canada each provided a letter of support, which was sent to their respective dive shops. Endorsement was also requested and received from the Vancouver General Hospital (VGH) Division of Hyperbaric Medicine. VGH operates a hyperbaric chamber and is the sole provincially designated facility for the treatment of recreational dive related DCI.

SCUBA TANK FILL INFORMATION

A database was developed of every fill station in the province. This included a contact person, telephone and fax numbers, mailing and e-mail addresses (when applicable). The number of fills made over the 14-month period from 1 October 1999 - 30 November 2000 inclusive was tabulated using survey information collected monthly from participating fill stations. Over this period, some fill stations went out of business while new ones opened. Some fill stations closed for various times during the winter. These changes were tracked and the database updated each month.

Two months before the start of the project, a letter was sent to every fill station. This letter announced the Abacus Project and requested each fill station's support and participation. The fill stations were informed that the goal was to count every fill made in the province for a period of 14 months.

A month prior to the beginning of the project, each fill station was supplied with a hand tally counter, a reminder card to display at the fill station, and staff training instructions. Fill station operators were instructed to train their staff and hang the enclosed counter on or near the yoke of the tank filler. Personnel were to push the button on the counter once for every fill made for recreational use (eg. air, nitrox, paid, air card credit, rental tank, free fill, personal use, pool training, open water instruction, instructor, student). At the end of each month, each fill station sent the total number of fills shown on the counter to DAN via telephone or e-mail.

It was crucial to the participation of several stakeholders that individual fill station fill reports be kept confidential. In order to protect the anonymity of the fill stations, a blind trust system was used for reporting and collecting the fill information. Each fill station was issued an identity code. DAN required the stations identify themselves by their code when reporting monthly fill information. The Abacus staff knew the identity of the individual fill stations and the corresponding codes but did not have access to the fill information for any of the individual stations. Monthly reports sent to the Abacus staff by DAN were limited to identifying whether stations had or had not reported. At the end of the data collection period, the central reporting agency provided the Abacus Project coordinator with only the total number of fills that had been reported by all stations for each of the 14 months.

Near the end of each month, fill stations were reminded to submit the count for the month. Each month the Abacus staff were advised which fill stations reported to the central reporting agency and which did not. This information was used to follow up by telephone with fill stations that did not report. Three attempts were made to request monthly fill information from stations that did not report. If a station still did not report and it was affiliated with a training agency, the name of the shop and its contact information was forwarded to a dive training agency representative who would telephone the non-reporting fill station. For fill stations that were not affiliated with a training agency and for those that were affiliated but still were not reporting after being contacted by the training agency representative, a dive shop operator who was a member of the UCBC Safety Committee telephoned the fill station to request their participation. If the fill station still did not report, no further attempts were made to request participation.

RECREATIONAL SCUBA DCI INFORMATION

All hyperbaric chambers in BC, the province of Alberta, Canada and western Washington State, USA, that were known to treat scuba divers were contacted. The Alberta and Washington chambers were surveyed because, historically, a significant number of people are known to travel from these areas to dive in BC waters. Each chamber was asked to do a file review for the 14-month period starting 1 October 1999 and to report the number of recreational scuba divers that had been treated for nonfatal DCI following one or more dives in BC waters.

RECREATIONAL SCUBA FATALITY INFORMATION

Recreational scuba fatality information was obtained from the BC Ministry of Attorney General, BC Coroners Service, which maintains centralized files for the whole province. The Coroners Service reviewed the Judgments of Inquiry for the 14-month survey period and provided copies of all reports that involved a scuba diving fatality to Project Abacus staff. A Judgment of Inquiry reports the facts determined as a result of the inquiry into a death.

Results

RECREATIONAL SCUBA TANK FILLS

A total of 146,291 recreational scuba tank fills were reported during the 14-month survey period and the number of stations that were operating fluctuated. The average number of stations in operation each month was 78 (range 76-84). Monthly reports were received from 65% of the province's fill stations (range 60-71 %).

TABLE 1
MONTHLY REPORTING BY FILL STATIONS

Fill stations	Month													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Total number	84	83	80	78	79	80	78	77	78	77	76	76	76	76
Number that reported	59	55	52	51	49	48	50	50	55	51	47	48	50	48
Percentage that reported	70	66	65	65	62	60	64	65	71	66	62	63	66	63

These results are summarized in Table I (above).

RECREATIONAL SCUBA DCI

During the survey period there were 14 recreational scuba divers treated for ‘ non-fatal DCI following one or more dives in BC waters. Eleven divers were treated in BC. One diver was treated in Alberta. Two divers were treated in Washington State. A total of five chambers were surveyed. The incidence of DCI was 0.010% (9.57/100,000 dives).

RECREATIONAL SCUBA FATALITIES

There were three recreational scuba fatalities during the survey. The BC Coroners Service’s Judgments of Inquiry listed all three fatalities as accidental deaths. The incidence of death was 0.002% (2.05/100,000 dives)

RISK OF DEATH AND DCI

Using fatalities, DCI cases and the total number of fills the combined incidence of death and DCI in recreational scuba diving was 0.012% (11.62/100,000 dives).

Discussion

Estimating the risk of recreational scuba diving is not possible without a trustworthy estimate of diving activity. The lack of an accurate denominator has obstructed the epidemiological analysis of recreational scuba diving.

Using the diver participation approach has proven to be problematic. It requires accurate information on how many people are diving. It is unknown how many people dive and usually only very crude estimates are available for a country or particular geographic area. For instance, one estimate of the number of people who participate in scuba diving as a sport in the United States ranged from 1.5 million to 3.5 million.[11] In a critical review of the methods used for estimating the risk of recreational scuba diving, Monaghan observed that industry estimates of the number of people who dive do not adequately take into account diver drop out or multiple certifications by one person, thereby inflating the estimated number of participants and minimizing the estimate of risk.[12] He suggested that a tenfold greater rate of diver deaths reported in Australia compared to that of the United States of America was most likely due to differences in how the number of divers (i.e., the denominator) was calculated.[13]

Using the diver participation approach is further compromised by the lack of a useful definition of what constitutes an “active diver”. For instance, the National Sporting Goods Association annual survey of sports participation defined a participant in scuba diving as an individual seven years of age or older who dives more than once a year.[14]

One study has used a reliable source of information for the denominator in the calculation of diver risk. In a review of five years of diving accidents treated by the accident and emergency department of a major hospital located near the largest inland diving centre in the United Kingdom, Hart et al used diver visits to the dive centre as an estimate of the number of participants.[15] From 1992 to 1996 there were seven deaths, for an incidence rate of 2.9 deaths per 100,000 diver visits.

In a risk analysis of recreational scuba diving instructors at work, Richardson reported morbidity and mortality rates using a diver participation approach (i.e., risk/instructor).[16] From 1989 to 1993 there were 28 cases of DCI and four deaths. The incidence of DCI ranged from four cases in 55,435 instructors (0.00007%) in 1992 to nine cases in 44,252 instructors (0.0002%) in 1991. The incidence of death ranged from none in 55,435 instructors (0%) in 1992 to one death in 27,543 instructors (0.00004%) in 1989.

Diving activity is considered the more appropriate denominator for calculating the relative risk of recreational scuba diving.[11,17] Using the diving activity approach, the focus is on the relative risk for each exposure to the activity. Information about the frequency of recreational scuba fatalities and DCI is compared to the number of dives performed. This approach requires accurate information on the number of dives being done. Worldwide, only a few studies of risk in recreational scuba diving have used the diving activity approach. The Abacus Project is the first multiple site field study to use a reliable diving activity method to investigate the risk of recreational scuba diving in a large geographic area over an extended period of time.

Gilliam reported on 77,680 dives done from a dive cruise ship over a 12-month period during 1989-90.[18] Seven cases of DCI were treated in the ship's recompression chamber, giving an incidence of 0.009% (9.01 cases per 100,000 dives). Wilmshurst et al attempted to gather recreational dive activity information in Great Britain.[17] They tried several methods, including sending an activity survey to 10% of British Sub Aqua Club (BSAC) members and asking "representative dive shops" to count dive cylinder fills. While DCI risk estimates are given for 1986 and 1990 BSAC members, the method used for calculating these estimates of risk is not described and no diving activity information is reported.

As part of the Richardson study of dive instructors at work, the risk of death and DCI during ascent training was calculated using a diving activity-based formula (ie. risk/ascent).[16] Eighteen cases of DCI and zero deaths were reported in 4,906,821 emergency ascents by instructors for an incidence of 0.0036 DCI cases per 100,000 instructor ascents. In a parallel study of the risk of emergency ascent training for open water trainees from 1989 to 1992, there were 33 injuries, including one case of DCI, and two deaths in 3,754,704 emergency ascents by trainees.[19] This corresponds to an injury rate of 8.7 injuries per 1,000,000 trainee ascents and 0.5 deaths per 1,000,000 trainee ascents.

With regard to the current study, it is unknown how many fills were done but not reported, as the study's design precludes the use of missing data techniques to predict this.[20] While monthly reports were sent by an average of 65% of the fill stations, it cannot be inferred that 35% of the fills were missed. The percentage of stations that did not report is not a predictor of the percentage of fills that were missed each month. For example, in month nine of the data collection period, 55 of 78 fill stations (71%) reported a monthly total of 10,737 fills while in month 10, 51 of 77 fill stations (66%) reported 14,617 fills. The number of fills not reported could range from none to an amount equal to or greater than the number reported.

Since the estimates of death and non-fatal DCI were calculated using the number of reported fills as the denominator, it is likely the estimates are conservative. If it is assumed that recreational fills were made but not reported, the revised risk estimates would be lower than those reported. However, the difference in risk estimates would not necessarily be significant.

Field research must often balance scientific rigor and practical limitations. The study did not have built in secondary checks of the authenticity of the tank fill or DCI information that was reported. This is an extremely common limitation in epidemiological and diving medicine field research. Using sampling procedures for verification of the accuracy of fill counts and medical file reviews for verification of diagnosis of DCI would improve the trustworthiness of the results.

Feedback from dive storeowners and charter operators who took part in the study provided anecdotal support for the accuracy of the tank fill counts each month. Reports filtered back to the investigators that many fill stations had not previously tracked fill information and were finding it valuable for business purposes. Other fill stations already had computer-based systems in place for tracking fill numbers and purpose (e.g., class, recreational, commercial). Informal reports from divers of no fill counters being seen at fill stations corresponded to those operations that were not sending in fill information.

The Abacus Project required fill stations to send in counts for 14 consecutive months. In comparison to other survey methods that require a single response, the project was demanding of the research cohorts. In spite of this, monthly reports were received from 65% of the fill stations. This is a significantly higher participation rate than that typical of survey investigations requiring a single response. With a maximum of 71% and a minimum of 60% of stations providing monthly reports, the participation rate was stable over the course of the data collection period. In future studies of this type, refinement of the follow-up procedures used with non-responding fill stations could further increase the percentage of stations reporting each month.

The high response rate may also reflect several other structural factors. The organisation that sponsored the Abacus Project, the UCBC, is generally considered a relatively neutral party. Its mandate is recreational diving safety and marine environment conservation. This neutral stance was enhanced by the endorsement of the project by all training agencies that conduct business in the province, by the blind trust strategy used for collecting the fill count information and by DAN acting as the central collection agent for the fill information.

The non-fatal DCI incidence rate of 9.57 cases per 100,000 dives for the Abacus Project is comparable to the 9.01 cases per 100,000 dives aboard the dive cruise ship reported by Gilliam.[18] However, the incidence of scuba deaths is different. Gilliam did not report any deaths during the one year study period, while the Abacus Project found a rate of 2.05 deaths per 100,000 dives.

Comparison of the number of dive fatalities during the Abacus Project to available information from the BC Coroners Service suggests that the survey period was representative. From 1985 to 1999 there were an average 2.53 fatalities per year.[9] The one year average for the Abacus Project was 2.57 fatalities. It was not possible to do a similar comparison for DCI since the annual incidence rate of DCI in BC is unknown.

In prior years there had been instances of student death and DCI in provincial waters. Therefore, fills for scuba students were counted. Two of the three fatalities that occurred during the 14 months of data collection took place during instructional dives. One was a student in a

basic open water course. The other was a student in an advanced open water course. The third fatality was an inexperienced open water certified diver accompanied by an instructor.

This project has established a baseline estimate of the risk of death and non-fatal DCI for recreational scuba diving in the province of BC. The results can be used as a reference point for future studies. Continuous tracking of recreational scuba diving activity, fatalities and DCI treatments in BC using the methods employed in the present investigation could help answer questions about diving trends and safety.

Research is needed on the risk of recreational diving death and DCI in other geographic areas. It is unknown whether the BC estimates of risk are applicable to other geographic areas. Differences in dive conditions (eg. water temperature, visibility, typical sea conditions) may influence the relative risks. Similarly, certain areas may attract divers who are generally at greater or less risk because of significant differences in physical and psychological conditioning, dive training and experience. Replication of this study in different geographic areas of the world where recreational scuba diving is popular is required.

Acknowledgements

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This project was presented at the Undersea and Hyperbaric Medical Society 2002 ASM, San Diego, Ca, USA.

Dr Gary Ladd is a registered psychologist with a special interest in dive psychology.

Dr Victor Stepan is a retired physician with an interest in hyper/hypobarics.

Ms Linda Stevens is a registered nurse in intensive care and hyperbaric nursing.

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Objectives of the Society
To Promote and facilitate the study of all aspects of underwater and hyperbaric medicine.
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