Original articles

Scuba injury death rate among insured DAN members

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Key words
Accidents, age, cardiovascular, deaths, diving accidents, DAN – Divers Alert Network, epidemiology

Abstract

(Denoble PJ, Pollock NW, Vaithiyanathan P, Caruso JL, Dovenbarger JA, Vann RD. Scuba injury death rate among insured DAN members. *Diving and Hyperbaric Medicine*. 2008; 38: 182-188.)
We calculated the annual rates of diving-related deaths among DAN-insured members in the period from 2000 to 2006 and investigated the effects of age and sex on death rate by logistic regression. We determined relative risks for divers < 50 and ≥ 50 years of age for drowning, arterial gas embolism, and cardiac incidents, the three most common disabling injuries associated with diving death. There were 1,141,367 insured member-years and 187 diving-related deaths. Males made up 64% of the members. Individuals ≥ 50 years of age constituted 31% of the fatalities. Insured mean age increased from 40 ± 12 to 43 ± 13 years over the seven-year study period. Annual fatality rates varied between 12.1 and 22.9 (average 16.4, 95% confidence intervals 14.2, 18.9) per 100,000 persons insured. The relative risk for male divers in their thirties was six times greater than the risk for female divers in the same age range. Fatality rates increased with age for both sexes, but the higher relative risk for males progressively decreased until the rates became similar for both sexes after age 60. Death associated with cardiac incidents was 12.9 times more likely in divers ≥ 50 years of age. We recommend that older divers adjust their participation in diving according to health status and physical fitness, maintain fitness with regular exercise, and abstain from diving in conditions likely to require unaccustomed physical activity.

Introduction

Recreational scuba diving is associated with hazards inherent to all water-related activities as well as hazards specific to underwater breathing and environmental pressure changes. Injuries from these hazards can be fatal and occur unpredictably. Recreational dive training organizations set standards for safe diving practices to prevent injuries, but the responsibility for safety is ultimately that of the individual diver. A lack of understanding of the risks may make divers less compliant with safe practices and undermine risk mitigation initiatives.

The definition of risk includes both the probability of an adverse event and the severity of its consequences, but the popular perception of risk seems to be affected only by severity, not probability.[1] In a survey of 444 subjects, for example, scuba diving was ranked as more risky than snow skiing but less risky than bungee jumping, rock climbing, motorcycle racing, hang gliding, cliff jumping and sky diving.[2] In fact, the actual likelihood of injury in open water recreational diving seems to be 100 times less than the likelihood of injury in snow skiing.[3] However, injuries in diving may involve higher mortality due to the associated hazard of drowning, the most common cause of diving-related deaths.[4]

Unlike subjective perception, objective risk estimation is based on knowledge of past occurrences of injuries, their frequencies, severity, numbers of persons exposed and measures of their exposure. Complete information is rarely available in recreational scuba diving. The annual count of injury deaths in the United States (USA) and Canada has been surveyed since the 1960s. Peaking at 150 in the mid 1970s, the death count has been fairly stable for more than a decade at 84 ± 5 (range 77–91).[5] Without knowing the number of persons exposed, however, it is impossible to compare the risk of drowning for scuba divers and non-divers or to establish the absolute risk of death associated with diving. Attempts to calculate rates using projected numbers of divers and dives have produced estimates ranging from 3.2 to 34 per 100,000 divers and from 0.37 to 4 per 100,000 dives.[6–12]

The British Sub-Aqua Club (BSAC) has reported death rates on a per-diver basis for its membership since 1959. The count of BSAC members varied between 3,000 and 42,000 and the annual number of deaths from 1 to 10. Annual rates varied between 6.0 and 58 per 100,000 members.[8] With so few deaths annually, random variations may substantially affect the death rate independent of changes in external causes or specific risk factors. The BSAC estimates do not address the incidence per exposure since the individual frequency of diving is reported only for subgroups of divers, such as those with diabetes.[13]

Frequency data have been available for some specialty areas like cave diving and scientific diving. Diving in caves

with the associated hazards of becoming lost or entrapped or exhausting gas supplies before reaching the surface, is known to be a higher-risk endeavour than diving in open water.[14,15] On the other hand, scientific diving, with strong organizational safety policies, appears to be less risky than open-water recreational diving. In 2003 for example, the American Academy of Underwater Sciences (AAUS) recorded 104,921 dives and no fatalities.[16]

Recent trends find an increasing number of older persons participating in recreational activities.[17] While complete diver population records are not generally available, Divers Alert Network (DAN) data indicate that the age of divers is increasing.[5] Cardiovascular disease has also become increasingly recognized as a factor in the death of older divers.[18] Given the low incidence of fatalities and missing denominators, associations of dive-related deaths with age and health issues have not been tested. Large data sets are required for sufficient power to address such effects.

DAN is a not-for-profit organization with a large membership and good access to scuba injury and fatality data for the USA and Canada. Member benefits include a 24-hour emergency line and dive accident and travel insurance. DAN receives information on incidents and accidents through direct involvement in cases and by collecting data through active surveillance programmes. We used data for insured DAN members to calculate the annual rates of diving-related deaths, the influence of age and sex on the rates, and the relative risks of divers above and below 50 years of age for the disabling injuries of drowning, arterial gas embolism, and cardiac incidents.

Methods

Since 2000, the DAN membership database has included information about age and sex. Data about deaths came from insurance claims and DAN's fatality surveillance programme. Each case reported through the surveillance programme was cross-checked with the DAN membership database. The study was approved by the Duke University Medical Center Institutional Review Board. We extracted de-identified information from the membership database for all living divers and merged it with fatality information. The final dataset consisted of all insured DAN members for the period of 2000 through 2006 with age, sex, and fatality indicators.

A scuba fatality was defined as the death of a diver equipped with scuba who had entered the water with the intent to dive and had died in the water or had left the water with a disabling injury and consequently died. In our analysis of 947 diving fatalities, the medical examiner specified drowning as the cause of death (COD) in 70% of the cases.[17] For the majority of divers who drowned, however, there was evidence that a prior disabling injury was directly responsible for death or for incapacitation followed by death due to drowning. Thus, we elected to focus on the disabling injury as more relevant to diving safety than the subsequent COD, drowning. We found the three most common disabling injuries to be drowning, AGE, and cardiac incidents, and in the present paper, we investigated the association of these injuries with age above and below 50 years.

The mean ages of DAN-insured members were calculated for each calendar year. Annual fatality rates per 100,000 insured members were calculated based on the number of fatalities and the number of insured members. We adopted the rate per 100,000 exposed people as this unit is used in most national injury statistics. Sex and age-specific mortality rates were calculated using aggregated data for the entire observation period. Mortality rates for the three most common injuries – drowning, arterial gas embolism (AGE), and cardiac events – were calculated separately for insured members of < 50 and ≥ 50 years of age.

Data are shown as mean ± standard deviation where applicable. The difference in mean age between sexes was tested using a two-sample Wilcoxon test with significance accepted at $P < 0.05$. Trends in mean age over time were tested by linear regression. Mortality rates were calculated by dividing the number of injury deaths by the number of insured members and multiplying by 100,000. Rates were shown with 95% confidence limits (CI). Effects of age and sex on fatality rates were tested with logistic regression using backwards elimination of non-significant variables ($P < 0.05$). Differences in the disabling injury-specific fatality rates were calculated as a relative risk (RR) with 95% CI. If the lower confidence bound was less than one, the difference was considered not to be significant.[19]

Results

There were a total of 1,141,367 insured member-years and 187 scuba diving-related deaths among them in the seven-year period studied. The age distribution by sex is shown in Figure 1. Males represented 64% of all insured members in this period. Divers in their forties were the largest subpopulation (30%) while divers ≥ 50 years of age represented 31% of all diving-related fatalities.

Figure 1
Age distribution of insured member-years
males – black; females – white

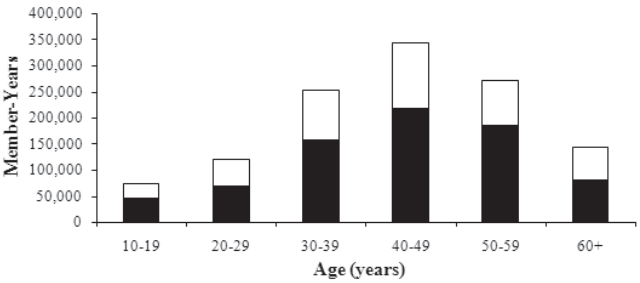
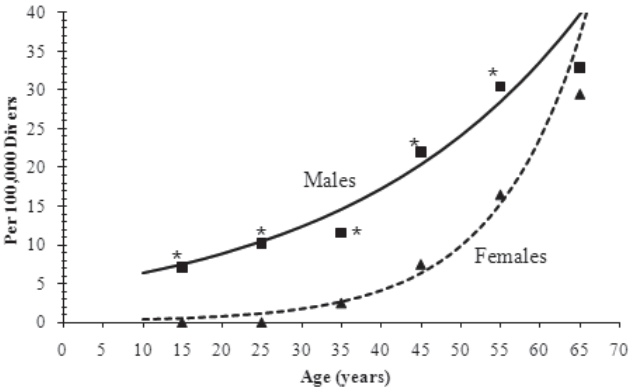


Figure 2
Fatality rates by gender and age. Lines indicate logistic regression-predicted rates, and squares and triangles represent mean values by sex for 10-year age groups; * indicates significant gender contrasts



The mean age of insured divers increased significantly from 2000 to 2006; from 41 ± 12 to 44 ± 14 years for males and from 39 ± 11 to 42 ± 13 for females. The pooled age increased from 40 ± 12 to 43 ± 13 years (median from 41 to 45, respectively). The percentage of divers 24 to 44 years of age decreased and the percentage of divers ≥ 45 years increased. The largest change was in age group 55–64, which increased from 9.2% (2000) to 18.1% (2006) of the total.

The overall rate for the seven-year period was 16.4 (95% CI 14.2, 18.9) per 100,000 persons, with annual rates varying from 12.1 to 22.9. The overall rate for males was 21.1 (95% CI 18.0, 24.7) and for females 7.6 (95% CI 5.4, 10.8). The relative risk for males was 2.8 (95% CI 1.9, 4.5) times the risk for females.

Raw composite data and logistic regression model results for rate by sex and age are shown in Figure 2. Logistic regression was conducted using continuous age data. The squares (male) and triangles (female) in Figure 2 represent mean values by sex for 10-year age groups. Fatality rates on a per-diver basis increase with age for both males and females. The rate for males was significantly higher for age groups < 60 years. The male fatality rate increased from 7.0 in teenagers to 33.0 per 100,000 divers in the ≥ 60 year age group. There were no recorded fatalities in females up to age 30 despite the fact that the participation rate was similar to that in the ≥ 60 year group. The female fatality rate increased from 3.0 in the 30–39 year age group to 29.1 per 100,000 divers in the ≥ 60 year group.

Logistic regression indicated there was an interaction between sex and age as shown by the convergence of the male and female risk lines in Figure 1 with increasing age. This is also reflected in Table 1 for the relative risks of males and females. The relative risk was significantly greater for men up to age 59 and similar thereafter. Values for the 10 to 29-year age range were extrapolated from the regression model.

There were sufficient data to investigate the probable disabling injury resulting in death in 129 cases of insured fatalities. The overall death rates as well as disabling injury-specific rates were compared in insured divers of ages up to 49 years and ≥ 50 years (Table 2). Presumed cardiac events were most common in the older group (37%), 13 times more likely (95 % CI 5.0–33.5) as a disabling injury than in the younger group. In addition, older divers had a greater relative risk both for AGE (RR 3.9) and drowning (RR 2.5).

Discussion

AGE OF INSURED DIVERS

The overall mean age of insured DAN members increased through the observation period. The representative portion was unchanged in the 15–24 year age group, decreased in the 25–44 year age groups, and increased in the 45 and older groups. This may indicate that young people still show the same initial interest for scuba diving but do not stay active for a long time. The largest increase in representation was in the 55–64 age group, reflecting the ageing diving population. We do not know how the age distribution of DAN members compares to other groups of divers.

Table 1
Relative risks of dive-related death by age and gender, [1] values based on regression model; * indicates significant sex contrasts

Age group (years)	Rate		Relative risk for males		
	Males	Females	RR	95% CI	
10–19	7	0	17[1]		
20–29	10	0	9.8[1]		
30–39	11	2	5.5*	1.3	23.6
40–49	22	7	3.1*	1.5	6.2
50–59	30	16	1.9*	1.1	3.4
≥ 60	33	29	1.1	0.5	2.8

Table 2
Cause-specific frequencies of death and age-dependent relative risks

Cause of death	< 50 years n=788,489	≥ 50 years n=352,878	RR	Lower limit	Upper limit
Cardiac	5	29	12.9	5.0	33.5
AGE	8	14	3.9	1.6	9.3
Drowning	15	17	2.5	1.3	5.1
Unknown	15	16	1.9	0.9	4.1
Other	7	3	1.0	0.2	3.7
Total	50	79			

OVERALL FATALITY RATE

In the current study based on a known number of insured members and number of dive-related deaths, we have established the death rate at 16.4 per 100,000 insured members for all ages and both sexes. The reliability of the rate depends on the validity of both the denominator and the number of deaths. In the case of DAN-insured members, it is likely that most deaths were captured.

A summary of previously published fatality rate estimates is given in Table 3. Estimates are presented both as the rate per 100,000 members and the rate per 100,000 dives, when available. BSAC and DAN fatality rates are computed from large datasets with measured denominators. Most of the published fatality rates are based either on small data sets,[11] surrogate measures,[9,10,12] or estimated denominators.[9,11,15]

The fatality rates per 100,000 divers derived from DAN Insured and BSAC data, 16.4 and 14.4 respectively, are reasonably similar given the expected variability and small total number of events. Despite variability, annual rates for the period 2000–2006 were not statistically different either. Conversely the rate of 3.4–4.2 per 100,000 divers rate from a study commissioned by the Divers Equipment and Marketing Association (DEMA) is much smaller, but the numerator and denominator were drawn from different sources.[20] The number of fatalities (the numerator) came from DAN data while the population at risk (the denominator) was estimated in a marketing study at between 2.1 and 2.7 million. Inaccuracy is likely when numerator and denominator are drawn from different populations.

A similar rate was estimated recently for Australia. Based on a survey of diving activities of overnight visitors to Queensland between April 2006 and March 2007 and the annual "participation in exercise, recreation and sport survey," the rate for combined local population and overnight visitors was established at 3.7 per 100,000 divers or 0.57 per 100,000 dives.[9] The erroneous use of overnight visitors as a denominator to calculate the annual rate per population probably led to underestimation of the actual annual fatality rates since for most visitors the outcomes were known only for the time of visiting rather then for the entire year. The estimated rate per 100,000 dives was the same as one in the study ordered by DEMA, possibly due to the same bias.

Using the reported number of tank fills as a proxy for the number of dives and fatality information provided by Coroner Services, the fatality rate per 100,000 dives in British Columbia, Canada was established with only three fatalities reported for the 14-month period. The validity of the estimate was further limited by the fact that only 65% of the identified filling stations participated.[12] The calculated rates were within the 95% confidence limits of those established by similar methods in Japan, and Victoria,

Table 3
Overview of recorded and estimated scuba injury death rates

Group	Denominator	Time period	Rate (95%CI) per 100,000 divers	Rate (95%CI) per 100,000 dives	Reference
Cave Divers, UK	Measured	1957–1979	–	138 (65, 300)	14
Cave Divers, UK	Measured	1980–2006	–	24.6 (12. 50)	15
USA	Estimated	1986	3.4–4.2	–	6
USA	Estimated	1989	16.7	0.8–1.6 (1.6, 12.7)	6
Orkney, Scotland	Measured	1999–2000	–	4	11
Australia	Estimated	1989	34	1.7–3.4	7
Victoria, Australia	Estimated by tank fill count	1992–1996	–	2.5	9
Australia	Estimated by survey	2000–2006	3.57	0.57	9
British Columbia, Canada	Estimated by tank fill count	1999–2000	–	2.04 (0.8, 6)	12
Japan	Estimated by tank fill count		(8.8, 33.8)	1 to 2.4 (0.5, 2)	10
BSAC	Measured	2000–2006	14.4 (10.5, 19.7)	–	8
DAN Insured	Measured	2000–2006	16.4 (14.2, 18.9)	–	Current study

Canada as well as the rates calculated from limited Orkney data.[9–11]

Fatality rates based on the number of participants do not take into account frequency of participation among individual divers. Per-dive-based rates established using known number of dives and accidents are rare in recreational diving. The AAUS reports no deaths in 104,921 logged and reported scientific dives.[16] Computing the upper 95% confidence limit it is expected that the mortality rate in scientific diving is less than 3 per 100,000 dives.

A British cave diving group has tracked its membership diving activity and accident data since 1957. Despite their small numbers, multi-year data indicate a significant decrease in the fatality rate from 138 (95% CI 60, 300) before 1980 to 24.6 (95% CI 18, 50) per 100,000 dives after 1990.[14,15] While improved, cave diving appears to be much riskier than recreational open water diving.

COMPARISON WITH OTHER INJURY DEATHS

According to the National Center for Health Statistics (NCHS) unintentional injury was the fifth leading cause of death in 2004. There were 117,809 fatal injuries making up 4.7% of all deaths in the United States. The overall death rate from injuries in the general population was 35.5 and from traffic accidents 16 per 100,000 persons annually.[17] The annual death rate of 16.4 per 100,000 divers is similar to the death rate due to heart attack while jogging (13 per 100,000 joggers).[21] It is important to remember, however, that these rates do not reflect exposure time. For example, the vast majority of persons will have much greater exposure to traffic situations than diving situations. The risk of diving-related death for scuba divers has been described as 13 times greater than the risk of drowning for the general population.[18] In this case, however, the rate for drowning was calculated based on the entire population rather than just those who were exposed to water hazards. This is very different from the diving-related death rates calculated for a group in which all members are exposed to diving hazards.

EFFECT OF AGE AND SEX ON DEATH RATE

The possible effects of age on risk of injury and death in recreational activities are of special interest due to the ageing of the general population and an increased participation of older people in recreational activities. For example, emergency medicine department reports indicate a substantial number of participants ≥ 65 years of age among those injured in recreational sports. They represented 17% of the injuries in golf, 15% in tennis, 9% in fishing and 4% of injuries in scuba diving (again with no exposure duration information).[17]

Our data indicate a clear effect of age and sex on the risk of death in diving. DAN-insured members ≥ 60 years of age have a relative risk four times greater than that of male teenagers. Young adult males have a four-fold greater risk than young adult females. Differences in risk associated with sex disappeared by 60 years of age. Youthful differences between sexes may reflect greater risk-taking by males, which may be related to testosterone.[22] However, the rates increased with age despite decline of testosterone levels.

The risk of dying during physical activity for older persons is associated with a high prevalence of heart disease. Persons 66–74 years are 27 times more likely to die from acute myocardial infarction than persons 35–44 years of age.[23] Responses to diving stress and exertion in persons with diagnosed and undiagnosed heart disease may cause death or weakness that is complicated by the possibility of drowning.[24,25]

Differences in fatality rates for males and females and their change with age may be partially explained by the different prevalence of heart disease in the two sexes. Oestrogen has long been considered a protective factor against heart disease in women, but recent epidemiological studies show only a relatively small effect.[26] Heart disease as an underlying risk in diving is hard to determine due to confounding effects of drowning and thus it may be underreported.[27] On the other hand, in the absence of evidence, the diagnosis may be biased toward cardiovascular disease-related causes in older victims. The diagnosis of disabling injury in our data was based on health history, accident scenario and autopsy findings.[18]

Excluding cardiac causes, which were suspected in one third of deaths in divers over 49 years of age, the fatality rate in older divers would still be greater than in younger divers (Table 1), as the relative risks for arterial gas embolism and drowning suggest. This may be related to a decline in physical ability – aerobic capacity, muscular strength, flexibility, coordination and dexterity – all of which may make older people prone to errors and more vulnerable.[17,28] Association of age with a relative increase of risk of death in diving requires additional research to establish its true meaning and possible causes.

The preventability of cardiac deaths in diving depends on divers' knowledge of their health risks, an appreciation of specific dive risks and a willingness to adjust behaviour which may be affected by readiness to trade risk for freedom. Some decedents in our database knew about their health status, but we do not know if they had sought specific evaluation regarding medical fitness to dive. Mandating strict annual medical evaluation outside of standard care would not necessarily contribute much to their self-knowledge. However, a fraction of decedents who were not aware of pre-existing conditions could have benefited from regular medical examinations. According to the American Heart Association (AHA), the screening for coronary artery disease risk factors should start at age 20. At this age it includes family and personal history. Most pre-participation questionnaires administered by training agencies fulfil this

purpose.[29] Divers over 35 might benefit from discussing their heart risk factors with their primary care physicians. In addition, the AHA suggests medically-supervised exercise stress tests in men over 40 years of age and women over 55 years of age who wish to engage in vigorous training or competitive sports and who have two or more coronary risk factors (other than age and sex) or one markedly abnormal risk factor. A selective approach to medical evaluation of fitness for diving based on individual risks seems most suited for recreational diving.[30]

The DAN membership indicates that a large number of older people chose diving for recreation. The benefits of this active lifestyle should not be underestimated, but stress and exertion (neither unique to diving nor the only factors that may precipitate sudden cardiac death) are hazards that must be considered when evaluating health and fitness to dive.[28,31] While there seems to be a broad consensus regarding criteria for medical fitness to dive, understanding the risks by both divers and their physicians is essential. The final decision to participate is up to the individual. Personal choices may go against medical advice but being properly informed makes this less likely.

Conclusions

We calculated fatality rates for DAN insured members and reported them with reference to the risk of mortality associated with other activities. The occurrence of dive-related deaths is rare and, even with a large group of divers, multi-year data are needed to investigate specific risk factors. We found that risk is greater for males and increases with age for both males and females. The most significant injury contributing to increased risk appears to be heart disease, but this alone does not account for all excess mortality. The risk of death associated with scuba diving reflects similar trends in injuries in the general population. Age itself is not a causative factor and more research is necessary to understand how age affects diving risk. Healthy lifestyle and regular physical activity affects quality of life, morbidity and mortality. All divers should take care of their health and maintain fitness with regular exercise. Older divers should regularly monitor their health and physical fitness and adjust participation accordingly.

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During the 1980s, the front page of the *SPUMS Journal* carried a series of cartoons by one of its members, Dr P Horne sadly now deceased, depicting a scene pertinent to that issue. This one, from a quarter century ago, highlights the growing concern at that time about cardiovascular health and the ageing recreational diving population.