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Epidemiology of morbidity and mortality in US and Canadian recreational scuba diving

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ABSTRACT

Objectives: This study investigates morbidity and mortality suffered by divers in the USA and Canada.
Study design: Prospectively recruited probability-weighted sample for estimating the national burden of injury and a weighted retrospective survey for estimating exposure.
Methods: The National Electronic Surveillance System and Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP) were searched for scuba diving injuries. The Divers Alert Network diving fatality database was searched for deaths, and Sports and Fitness Industry Association estimates for diving were obtained from annual surveys.
Results: In the USA, there were an estimated 1394 emergency department (ED) presentations annually for scuba-related injuries. The majority (80%) were treated and/or released. There were an estimated 306 million dives made by the US residents 2006–2015 and concurrently 563 recreational diving deaths, a fatality rate of 0.18 per 10^5 dives and 1.8 per 10^5 diver-years. There were 658 diving deaths in the US 2006–2015 and 13,943 ED presentations for scuba injuries, giving a ratio of 47 diving deaths in the USA for every 1000 ED presentations. There were 98 cases of scuba-related injuries identified in the CHIRPP data. The prevalence of scuba-related injuries for patients aged 3–17 years was 1.5 per 10^5 cases, and the prevalence of scuba-related injuries to patients 18–62 years was 16.5 per 10^5 cases.
Discussion: In Canada and the USA, only one out of every 10,000 ED presentations is due to a scuba-related injury. That there are 47 deaths for every 1000 ED presentations for scuba injuries speaks to the relatively unforgiving environment in which scuba diving takes place. For 1.8 deaths per million recreational dives, mortality in scuba diving is nonetheless relatively low.

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Introduction

Scuba diving is a popular recreational pursuit enjoyed by millions of divers in the USA and Canada,[1] though it exposes divers to stresses that sometimes result in injuries. The pressure exerted upon a diver increases by 1 atm for every 10 m of seawater depth, effectively doubling when a diver descends from the surface to 10 m depth in the sea. Once a diver is submerged and then breathing, gas (usually air) is delivered at a pressure equivalent to the ambient pressure at whatever depth the diver is at. Therefore, the deeper a diver dives, the faster the air in the scuba tank is consumed, and the more gas is taken up by the diver's tissues. Immersion also contributes to the physiological stresses a diver experiences. Drowning is the leading cause of death in diving, often after running out of gas, followed by cardiac causes and arterial gas embolisms.[2] Barotrauma from expanding gas during ascent, or from compression of the air spaces within the diver during descent, are the most common injuries reported to Divers Alert Network (DAN) each year through the 24-h diving emergency helpline.[3] DAN is a not-for-profit diving safety organization that provides assistance to divers in need of medical help, monitors diving injuries, studies their causes, and provides training in first aid and diving medicine.

Decompression sickness (DCS) and arterial gas embolisms are commonly referred to collectively as decompression illness (DCI). Other hazards faced by scuba divers include hazardous marine life encounters, trauma, sprains and strains from heavy scuba equipment, boating injuries, falls while wearing scuba equipment, and a myriad of other injuries. The risk of diving injuries for the population is not available because of a lack of data. The incidence data for diving injuries among recreational divers is incomplete because they are not mandatory reportable, unlike in military or scientific divers. There are two main rates of interest in diving: the number of injuries or deaths per 10^5 dives and per 10^5 divers per year.[4]

Morbidity rates

Dive conditions and dive populations vary across the world and, thus, injury rates may vary too. Over the 12-year period 1995–2007, the number of divers treated for DCI in Australia numbered 3558.[5] Over the same period, participation in sport surveys suggested that this amounted to a DCI rate of 10.7 cases per 10^5 dives.[5] In Canada, the number of air fills sold within a defined region was used to estimate that 146,291 dives had been made between 1999 and 2000, during that time, there were 14 known injuries, amounting to a rate of 9.7 cases per 10^5 dives.[6] A similar earlier study at a military base in Okinawa noted 94 cases of DCI between 1989 and 1995 and an estimated rate of 13.4 cases per 10^5 dives.[7] In the warmer Caribbean, a study conducted in 1989–1990 noted 77,680 dives and seven cases of DCS, giving a rate of 9.0 cases per 10^5 dives.[8] A 1990 British study of 36,434 divers found 6.7 cases of DCI per 10^5 dives.[9] In Japan, a survey of 3078 recreational divers between 1996 and 2001 found a reported incidence of DCS at 5.2 cases per 10^5 dives and a combined incidence of ear or sinus barotrauma, or DCS, of 49.3 injuries per 10^5 dives.[10] Numerous smaller studies have reported rates outside the aforementioned range, possibly due to wider confidence intervals (CIs) associated with small sample sizes. In diving morbidity research to date, efforts have focused on diving cohorts, for example, customers of dive businesses in a geographically defined area, or members of DAN. To our knowledge, no previous research has extracted scuba diving injury cases from much broader public health data.

Mortality rates

Using sports survey data, between 2002 and 2006, the fatality rate in Australia was estimated at 0.57 per 10^5 dives.[5] This was lower than found after counting the number of air fills sold, in British Columbia 1999–2000 at 2.05 per 10^5 dives, or in Okinawa 1989–1995 at 1.3 per 10^5 dives.[6,7] At a popular flooded quarry in the United Kingdom, mortality over a 5-year period was observed to be 2.9 per 10^5 visiting divers.[11] Among members of the DAN 2000–2006, the overall mortality rate was found to be 16.4 deaths per 10^5 insured person-years, but mortality per 10^5 dives was not available due to the lack of exposure data.[12] More recently, DAN Japan reported a lower membership mortality rate over 2004–2012 of 6.9 deaths per 10^5 member years, whereas in Australia, similar to the previously mentioned result, a rate of 0.5 deaths per 10^5 dives was based on annual surveys of Australian residents.[3,13]

Preventive efforts

Since the development and widespread adoption of the internet, divers have greater access to diving safety information than at any time previously. Concurrent with the growth in internet access, scuba diving equipment has continued to improve (for example, modern diving computers are now worn by the majority of divers), diver training is more widely available today than ever before, and professional dive guides can be located as easily as clicking a mouse. It is, therefore, possible that diving is safer today than ever. What is not known are the current rates of morbidity and mortality suffered by divers in the USA and Canada each year. This study aimed to determine scuba diving–related morbidity and mortality based on publicly available emergency department (ED) data in the USA and Canada.

Methods

In the USA, the Consumer Product Safety Commission (CPSC) maintains the National Electronic Surveillance System (NEISS), a national register of ED presentations at around 100 hospitals in the USA and US Territories. The data are sample probability weighted to reflect the ~5000 EDs in the wider US and US territories, deidentified, and each year, the previous year's data are made publically available through the CPSC web site. NEISS data have been used to describe a wide variety of injuries such as those resulting from paintball guns,[14] surfing,[15] and burns.[16] NEISS data for 2006–2015 were obtained from the CPSC web site (www.cpsc.gov/en) and imported into Windows Notebook as tab-delineated text. Product