Danish diving-related fatalities 1999–2012

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Abstract

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Aim: The purpose was to explore causative tendencies among diving fatalities to prevent similar injuries in the future.

Methods: We report 33 fatal diving injuries that occurred among Danish divers during the period 1999–2012 in Scandinavian waters. The study was performed as a retrospective overview. The empiric data consists of police reports, forensic autopsy reports and examination of the diving equipment. Data were assembled and analyzed using Pivot and Excel. Frequencies and means (+/- SD) were used to describe categorical and continuous variables respectively.

Results: The mean age was 38.9 years and drowning was considered the cause of death in 24 of 28 divers for whom a diagnosis was possible. Elevated body mass index (18 of 22 divers had a BMI > 25) was overrepresented in our group compared to the background population. A drysuit was worn by 17 divers. Diving independently of a dive centre and mishandling of buoyancy aids were common risk factors. Only two divers released their weights. Three-quarters of those who did not would have increased their chance of survival by doing so; nevertheless, in a quarter of cases the weights were not readily releasable or not releasable at all.

Conclusion: Unfamiliarity with drysuit diving, lack of a diving buddy and mismanagement of weights were important contributors to diving injuries.

Key words

Diving injuries; diving deaths; buoyancy; drowning; scuba diving; root cause analysis

Introduction

Diving for recreational purposes has gained increasing interest among Danes during recent years. There are currently 8,500 members of the Danish Sports Diving Association spread over 160 local diving organizations. Furthermore, a significant number of professional diving schools are operating to train recreational divers in numbers that equal the number trained by the National Federation. These represent different professional diving organizations, for example, the Professional Association of Diving Instructors, National Association of Underwater Instructors and Scuba Schools International.

A dive certificate, which includes instruction in various safety procedures and a medical review, is not required to dive in Denmark. The law regulates diving equipment sales and these must be CE-certified, but there are no regulations for the general maintenance of this equipment, except for pressure cylinders which are required to be pressure-tested regularly.[1] Hence, it is the responsibility of the diver to ensure that he or she is ready for the dive to be undertaken. The maintenance of medical, physical and psychological fitness, knowledge and competence lies within the hands of the individual diver. As reviewed in this article, this responsibility is not always complied with, resulting in sometimes fatal consequences.

In an analysis of diving-related injuries and fatalities in Denmark between 1966 and 1980, 30 divers died over a 15-year period, with an increasing incidence over time.[2] Similar analyses have been conducted in our neighboring countries; Sweden (1960–1976) and Norway (1983–2007).[3,4] However, a quantitative report on fatal diving injuries in Denmark has not been published since 1982. The present study aimed to investigate fatal diving injuries in Denmark, with the intention of exploring potential causes, in order to disseminate recommendations that might prevent similar diving injuries in the future.

Methods

DATA COLLECTION

The study was performed as a retrospective analysis of diving fatalities in Danish and other Nordic waters during the period of 1999 through 2012. Data collection was approved by the Danish Data Protection Agency (reference no: 03861) and upon individual request in each case from relevant government-regulated authorities and local police departments. The study abides by the principles of the Declaration of Helsinki. The empiric data consisted of police reports describing the circumstances surrounding each fatality, post-mortem forensic autopsy along with toxicological testing and examination of the dive equipment used. Data were primarily collected from the Danish Maritime Authority archives or from the local police responsible for the diving injury investigations. Additional information was gathered from the webpage <www.hyperbar.dk>, the Danish Navy Diving School and Technical Department and Norwegian Underwater Institute (Jensen R, personal communication, 12 November 2013).

DATA ANALYSIS

Two reviewers reviewed the files and data were analyzed using Pivot tables and diagrams in Excel. Frequencies and means (+/- SD) are used to describe categorical and continuous variables respectively. Not all parameters were described in every case. When calculating frequencies (e.g., of alcohol intoxication), we used the number of cases where this parameter was described as the total (i.e., the total number of cases where toxicological screening was performed). When a parameter was inaccessible, either because the file was incomplete or because it was not described in the file, we noted the parameter as 'not specified' (NS). Data included gender, age, year of diving injury, body mass index (BMI), the autopsy result including the type of death, cause of death, pre-existing illnesses, toxicological testing and other related conditions, technical defects of the dive equipment, type and ownership of the dive suit, type of breathing apparatus and gas used for diving. In addition, safety factors included the type of diving certificate, whether or not the diver was using a diving computer, dive time and depth, bottom time and the degree to which the dive was organized and planned.

'Organized' was defined as through a company or dive centre and 'planned' was the type of principle applied to deliberately prevent decompression sickness. Circumstances leading to the diving injury included visibility, the phase of the dive, the presence of a psychological panic reaction described by witnesses and nitrogen narcosis. Additionally, we applied an assessment practice to the process and summarized the proceedings and triggers leading to the diving injury in a root cause analysis.[5] Furthermore, positive buoyancy was evaluated by whether the weights were released during the event of the diving injury, and if the outcome could have been improved by ditching the weights.

Results

A total of 33 diving fatalities among foreign divers in Danish waters and Danes diving in Scandinavian waters during 1999 through 2012 were recorded, with a mean of 2.4 per year. Fourteen cases contained complete information, whereas nine cases lacked forensic examination reports, Thirteen cases lacked examination of the diving equipment and four cases lacked both. In eight cases, the circumstances around the diving injury were reproduced from sources other than original police records, such as newspaper reports from interested organizations and official reports.

DEMOGRAPHY

The age span was 21–59 years (mean 38.9 +/- 11 years); half were over 40 y.o. Among the deceased, there were 26 males and seven females. The incidence of death by season showed the majority occurred during summer, and only one fatality occurred during winter. The purpose of the dive was recreational except for one victim who was in training to obtain her certificate, two were professional divers and one victim was performing an errand when the incident occurred (trying to recover a pair of lost sunglasses). Table 1 shows a summary of the diving fatalities.

SAFETY PRECAUTIONS AND PRE-DIVE PREPARATION

The experience of the deceased diver was classified into six categories (Table 1). The sample shows a predominance of novice divers and only two professional divers. Twelve of the 33 cases were classed as organized dives. Nineteen dives were privately arranged, whilst the two professional divers were not included in this category. All of the divers who were uncertified were diving independently of an organized dive association, (except the diver in training). Twenty-three were diving with a buddy, five connected by a buddy line and ten were using a mooring line, fixed between the surface and the dive site. In 13 cases, the dive was planned using a dive computer. Only five reports suggested preparation for the dive using dive tables and in six cases it was deducible that no planning had occurred prior to the dive.

CIRCUMSTANCES LEADING TO THE FATALITY

The possible cause and trigger leading to each fatality are summarized using root cause analysis (Table 2). Fatalities were rarely caused by a single factor; rather, they followed a chain of events with a number of contributing factors. In 12 cases, failure, error or improper operation of the equipment was the main trigger and, in four additional cases, equipment factors may have disabled the diver from regaining control and thereby contributed to the outcome. For example, one diver lost drysuit control with air trapped in the legs, panicked and drowned. The subsequent testing of the equipment showed that the regulator took in water when turned upside down. Seven diving injuries were triggered by environmental factors; these were either a strong current or entrapment/entanglement. The psychological factors were nitrogen narcosis, occurring in two cases (range 41–53 metres' seawater (msw), breathing air) and 11 were reported by eyewitnesses to have shown signs of panic at the time of the incident. In two cases, the diver ran out of air and signalled this properly to the dive buddy; however, the subsequent rescue procedure was unsuccessful. In another two cases, the dive tanks were found to be empty when the diver was rescued but the events leading to the incidents were not witnessed. The pathophysiological factors comprised a wide range of conditions (Table 1), the most serious being cardiac factors, with two fatalities directly related to cardiac disease and another three fatalities being linked to poor cardiopulmonary fitness.

We classified the maximum depth of the dives into four categories based on certification depth ranges. A large proportion (10 of 30 divers) of diving injuries occurred

Table 1
Summary of diving related fatalities; BMI – body mass index; NA - not available; NS - not specified; SSBA - surface support breathing apparatus

Diver #	Year	Age (y)	Sex	Height (cm)	Weight (kg)	BMI (units)	Certification level	Dive Purpose	Organized dive	Depth (max. m)	Incident	Weights released	Breathing apparatus	Autopsy	Buddy status
1	2012	43	M	194	100	26.6	Advanced	Spearfishing	No	5	Bottom	No	Rebreather	Yes	Solo
2	2012	39	M	174	85	28.1	Novice	Recreation	No	8	Bottom	No	Scuba	Yes	Buddy
3	2012	21	M	NS	NS	NS	Novice	Recreation	No	15	Ascent	No	Scuba	NS	Solo
4	2012	44	F	175	78	25.5	Novice	Recreation	Yes	20	Bottom	No	Scuba	Yes	Buddy
5	2012	44	M	179	81	25.3	Advanced	Recreation	Yes	20	Ascent	No	Scuba	Yes	Buddy
6	2012	50	M	182	103	31.1	Novice	Recreation	No	11	Ascent	No	Scuba	Yes	Solo
7	2011	35	M	188	96	27.2	NS	NS	No	NS	NS	NS	NS	Yes	Solo
8	2011	21	F	168	67	23.7	Novice	Errand	No	8-9	Surface	No	NS	Yes	Solo
9	2011	44	M	183	108	32.2	Novice	Recreation	No	2−3	Surface	No	Scuba	Yes	Solo
10	2011	46	F	167	77	27.6	Novice	Recreation	No	3−4	Bottom	No	Scuba	Yes	Buddy
11	2010	38	M	NS	NS	NS	Novice	Recreation	No	30−70	Bottom	No	Scuba	No	Buddy
12	2010	45	F	NS	NS	NS	Novice	Recreation	No	30−70	Bottom	NS	Scuba	No	Buddy
13	2010	41	M	NS	NS	NS	Professional	Professional	NA	41	Bottom	No	SSBA	No	Solo
14	2008	NS	M	NS	NS	NS	Advanced	Recreation	Yes	42	Bottom	No	Scuba	No	Buddy
15	2007	38	F	176	115	37.1	Not certified	Recreation	No	3	Bottom	No	Scuba	Yes	Buddy
16	2007	45	M	NS	NS	NS	NS	Recreation	Yes	40	Ascent	NS	NS	Yes	Buddy
17	2007	59	M	190	109	30.2	Novice	Recreation	Yes	34	Ascent	No	Scuba	Yes	Buddy
18	2007	44	M	176	88	28.4	Novice	Recreation	No	3	Surface	No	Scuba	Yes	Buddy
19	2006	46	M	169	80	28	NA	Recreation	Yes	0	Surface	NS	NS	Yes	Buddy
20	2005	59	M	NS	114	NS	NA	Recreation	No	0	Surface	NA	NA	NS	Buddy
21	2004	23	M	183	92	27.5	Not certified	Recreation	No	2	Surface	No	Scuba	Yes	Solo
22	2003	44	M	173	81	27.1	Novice	Recreation	No	3	Bottom	NS	NS	Yes	Solo
23	2002	42	M	NS	NS	NS	Advanced	Recreation	No	NS	NS	Yes	Scuba	NS	Buddy
24	2002	32	M	NS	NS	NS	Advanced	Recreation	No	150	Ascent	NS	NS	No	Buddy
25	2002	35	M	168	71	25.2	Professional	Professional	NA	NA	NA	NA	SSBA	Yes	Solo
26	2001	30	F	185	109	31.8	Advanced	Recreation	Yes	NS	NS	No	Scuba	Yes	Buddy
27	2001	34	M	184	NS	NS	Advanced	Recreation	Yes	53	Descent	No	Scuba	Yes	Buddy
28	2001	35	M	180	75	23.1	Advanced	Recreation	No	3	Bottom	No	Scuba	Yes	Buddy
29	2001	22	M	189	69	19.3	Not certified	Recreation	No	1−3	Bottom	No	Scuba	Yes	Buddy
30	2001	30	M	NS	NS	NS	Novice	Recreation	Yes	42	Bottom	No	NS	No	Buddy
31	2000	45	M	177	83	26.5	Novice	Recreation	Yes	43	Bottom	NS	Scuba	Yes	Buddy
32	1999	49	F	163	78	29.4	NA	Recreation	Yes	0	Surface	Yes	NA	Yes	Buddy
33	1999	23	M	170	66	22.8	Novice	Recreation	Yes	24	Bottom	NS	Scuba	Yes	Buddy

Table 2. Root cause analysis in 33 Danish diving fatalities

Diver	Trigger	Disabling agent	Disabling injury	Cause of death
1	Rebreather; low O_2	Poor cardiopulmonary fitness; hypoxia	Asphyxia	Drowning
2	Missing valve on BCD; no buoyancy control	Negative buoyancy; weights not releasable; panic	Unknown; asphyxia?	Drowning
3	Resistance at second stage	Respiratory difficulty? Panic; negative buoyancy; weights not releasable	Unknown; asphyxia?	Drowning
4	Tight drysuit neck; buoyancy-related; inversion	Respiratory difficulty; laryngeal haematoma; aspirated when inverted	Asphyxia	Drowning
5	Strong current; regulator free-flow	Panic; ascent-related	Air embolism	Barotrauma
6	Out of air	Negative buoyancy; weights not released; panic; solo-dive	Aspiration; asphyxia	Drowning
7	Unknown; solo-dive	Poor cardiopulmonary fitness	Unknown	Drowning
8	Loss of swim fin; negative buoyancy	Panic; weights not releasable	Unknown; asphyxia?	Drowning
9	Dropped BCD at surface; Submerged by connection to inlet valve on dry suit	Loss of air supply; aspiration	Asphyxia	Drowning
10	Drysuit; buoyancy-related; inverted position	Panic; weights not releasable	Sudden respiratory difficulty after surfacing	Cerebral hypoxia/ drowning
11	Entrapment in wreck	Unknown	Unknown	Unknown
12	Entrapment in wreck	Unknown	Unknown	Unknown; corpse not recovered
13	Stricture on air supply (surface supplied)	Nitrogen narcosis; problem with communication with surface	Asphyxia	Drowning
14	Fits or epilepsy? Nitrox-related?	Oxygen toxicity? Panic?	Unknown; asphyxia	Unknown
15	Ear barotrauma; panic	Negative buoyancy; lack of BCD and swim fins; weights not releasable	Asphyxia	Drowning
16	Unknown; out of air	Panic; ascent-related?	Unknown; asphyxia?	Drowning
17	Out-of-air; panic	Emergency ascent; poor cardiovascular fitness	Barotrauma? Asphyxia	Drowning
18	Negative buoyancy; panic; Sudden unconsciousness at surface	Weights not released; aspiration?	Unknown; asphyxia?	Drowning
19	Cardiac incident; immersion	Unknown	Cardiogenic shock	Natural death
20	Cardiac incident	Poor cardiovascular fitness	Acute myocardial infarct	Natural death
21	Inexperience; improper operation of equipment	Buoyancy-related – water in BCD; aspiration	Asphyxia	Drowning
22	Unknown; solo-dive	Unknown	Unknown	Drowning
23	Entanglement	Strong current; loss of air supply	Asphyxia	Drowning
24	Gas supply-related; 150 m dive on heliox and O_2	Ascent related? Panic?	Unknown	Unknown
25	Entrapment during overhead diving	Strong current; loss of air supply	Asphyxia	Drowning
26	Strong current; separated from buddies; panic	Night dive; darkness	Unknown	Drowning
27	Deep dive; narcosis	Separated from buddy	Asphyxia	Drowning
28	Unknown	Unknown; not fit for diving; traces of cocaine and alcohol	Unknown	Drowning
29	Unknown; out of air?	Unknown; not fit for diving; traces of alcohol; inexperience; uncertified	Unknown; asphyxia?	Drowning
30	Dry suit; improper operation of equipment	Negative buoyancy; weights not released; panic; loss of air supply	Asphyxia	Unknown
31	Improper fixation of air cylinder	Resistance to breathing; aspiration	Laryngospasm; asphyxia.	Drowning
32	Exhaustion; panic	Poor cardiopulmonary fitness; aspiration	Unknown; asphyxia	Drowning
33	Entrapment in wreck	Damaged buddy line; separated from buddy; poor visibility	Unknown; asphyxia	Unknown

during dives > 30 msw with a maximum recorded depth of 150 msw, performed by a scuba diver breathing a mixture of helium and oxygen. This number includes the two professional divers who were breathing from a surface supplied umbilical. An equally high proportion (n = 12) occurred at depths < 5 msw.

Most of the fatalities (n = 15) occurred at the maximum depth of the dive. Seven fatalities occurred at the surface and of these three scuba divers died prior to submersion, two of whom felt discomfort after immersion and later autopsy showed death due to cardiac disease. A third diver also felt discomfort and exhaustion after immersion and lost consciousness and respiration on the surface. It was reported that the body was submerged briefly during the subsequent rescue attempt. The autopsy showed atherosclerosis and adiposity, but revealed no specific cause of death apart from signs of drowning at autopsy. Four divers deceased at the surface following ascent.

CAUSE OF DEATH AND CONTRIBUTING FACTORS

The body of one diver was never recovered. The primary factors causing death were classified into groups based upon the conclusions of the autopsy and witness statements. The principal cause of death reported was drowning, accounting for 24 victims. The autopsy was definite about barotrauma in only one diver, whilst in two cases the causes of death were cardiogenic shock and acute myocardial infarction.

A forensic autopsy was available in 24 of the 33 divers. Beside the two cardiac disease cases mentioned above, there were 11 divers who had signs of pre-existing diseases reported at autopsy. The most common findings were cardiomegaly (n = 4) and atherosclerosis (n = 6). BMI was obtainable in 22 divers, 18 of whom had a BMI > 25 and five of these had a BMI > 30. Toxicological screening was performed in 17 cases; however, the results were only available to us in 11 cases. Two were positive for cocaine, a third for antidepressants, two divers tested positive for ethanol and one had traces of both cocaine and ethanol.

Information about medical history was obtained in 22 cases and, of those, six cases were known to have one or more risk factors for cardiovascular disease (primarily hypertension, diabetes and adiposity). This group had an average age (45 years) that was six years older than the rest of the cohort and four of these had atherosclerosis at autopsy. However, four of the victims with no previous medical history of cardiovascular disease had signs of it at autopsy.

DIVE EQUIPMENT

The majority of deceased divers (n = 21) were using open-circuit scuba. Two divers were on surface supply and one was using a rebreather. Seventeen divers were diving in a drysuit and nine in a wetsuit. In five cases, information regarding the type of suit was unavailable and in two cases they were diving in regular swimwear. Only in three cases was it explicitly stated that the diver was unfamiliar with drysuit diving and in one case the diver was wearing an unaccustomed, new drysuit and got into trouble with her buoyancy. In the remaining drysuit cases, the diver's level of experience was unknown.

The vast majority of cases were diving using compressed air. Only five of 26 divers were out of air at the time the victim was recovered, the remainder still having air left in their tanks on examination. Particular information on residual air was lacking in five cases. Of the 25 divers who were known to use weights, only two ditched their weights during the course of the diving incident. Through careful review of these cases, it is thought that in 21 cases the odds of survival would have been enhanced if the diver had dropped their weights, improving the probability of reaching the surface alive. Six divers had placed their weights in such a manner that they could not be released easily in an emergency.

EFFICIENCY OF FIRST AID AND LIFE SUPPORT

The last step in the chain of events when rescuing a diver is efficient first aid, resuscitation and oxygen administration. In 17 cases there was no specific first aid equipment available in proximity to the diver, even though four of these dives were organized dives. In nine cases, the diver received basic first aid and only in 11 cases was the diver treated with oxygen. In three of these cases, the oxygen was available and administered at the scene by other divers or instructors, and in the remaining cases the oxygen was delivered by an emergency health care provider upon arriving at the scene.

Discussion

GENERAL DEMOGRAPHY

The absolute number of known fatal diving injuries has increased over the past two decades with a mean of 2.4 per year in our study and a mean of two per year in the earlier study from 1966 to 1980).[1] However, in that study, the incidence increased steadily during the period reviewed with a mean of three deaths per year in the latest five years. In neither study period are the numbers of active divers or the number of divers known, so fatality rates cannot be estimated. Since the previous Danish study, diving with nitrox and mixed gas, including with rebreathers, has been introduced, typical diving profiles have changed from bounce-dives to multi-level dives and dive computer use is more widespread.

CAUSES OF DEATH AND GENERAL HEALTH

In the recent study on fatal diving injuries from Norway, which included 40 scuba divers, surface-supplied and saturation divers, 31 divers were reported to have

Table 3
Comparison with similar studies from Norway and Australia; *no data for six divers

	Total number	**Number per year**	**Mean age** (y)	**Number drowned**	**Cardiac disease**
Norway (1998–2007)	40	4.4	31.4	31	6
Western Australia (1992–2005)	24	1.8	39.2	16	8
Denmark (1999–2012)	33	2.4	38.9	24 of 27*	8 of 27*

drowned.[3] Five died from sudden decompression, two from barotraumas, one from mechanical trauma and only one diver died from cardiac disease. BMI measurements were obtained in 39 divers; however, only four divers were found to be obese and there was no correlation between BMI and cause of death. Six divers had medical histories that included lung surgery, hypertension, diabetes and coronary artery disease. These conditions might have contributed to the incident, but could not be directly linked as the cause of death.

A recent epidemiological analysis among insured members of DAN found that their mean age had increased over time.[5] The risk of mortality was greater for men and increased with age for both sexes. According to this study, cardiac disease was the most significant risk factor for death during diving, the risk being 12.9 times greater in divers > 50 years of age.[5] Other authors have brought the topic into focus with similar work.[6–9] Amongst these, in a Western Australian study of 24 recreational divers who died whilst diving over a 14-year period (1992–2005), the mean age of the divers was 39.2 years old.[7] In two-thirds of the cases drowning was considered the immediate cause of death. Cardiac issues were noted in eight cases with a mean age of 50.3 years. Our study showed a similarity to these data (Table 3); but in only two divers was death directly attributed to cardiac disease.

Most remarkable was that 18 of 32 divers in our study were found to have a BMI above 25, whereas this is only true for 47% of the general population (The National Health profile 2014, Danish National Board of Health). The BMI measurements were obtained from the autopsy report and, therefore, their availability was solely dependent on whether or not an autopsy report was accessible. Although our cohort is a selected population, this discrepancy in BMI measures suggests the possibility that adipose people practice diving more frequently than people of normal weight or that there might be an increased risk of death in divers with a higher BMI.

In the comparable study from Norway, toxicological screening was performed in 33 out of 40 cases, and one diver had a positive blood ethanol. Another two divers had positive urine ethanol concentrations indicating previous alcohol consumption.[3] In our study, four divers showed traces of either ethanol or drugs; however, the relationship between intoxication and cause of death was not apparent.

The most common psychological factor was panic. Panic occurred in nine cases either as the eliciting factor or as a significant contributor that arose during the sequence of events. Panic as a psychological factor was only noted in cases where affirmed in a witness statement. Equipment was also noted as a trigger in cases where it was poorly maintained, failed or used improperly.

SAFETY PRECAUTIONS

In the study from Western Australia, faulty equipment contributed to only two cases.[7] The safety rules most often broken were: maintaining the buddy system throughout the dive; planning the dive with a buddy; maintaining good physical and psychological health; use of surface support when feasible and establishing positive buoyancy in an emergency.

The waters around Denmark are relatively cold with a mean temperature of 17°C during summer where the majority of the fatalities occurred. However, it is not mandatory to wear a drysuit under these temperatures and wetsuit diving is practiced and taught at the majority of commercial diving courses in Denmark. Nevertheless, nearly two-thirds of the fatalities in our cohort were using a drysuit. Lack of buoyancy control in relation to drysuit diving might have been a contributing factor in some of these accidents, and attention should be placed on this topic to reduced future incidents.

Establishing positive buoyancy by the release of weight underwater is a mandatory element in dive training because it can be a critical response to threatening circumstances. In every published study of scuba diving fatalities that we have reviewed, many divers failed to drop their weights. In our study, some had even placed their weights in such a manner that they could not be released easily or at all in an emergency, so this training message is not getting through.

The initiation of first aid immediately after a diving injury and in particular administration of 100 % oxygen is the gold standard for diving injury management regardless of whether the diver suffers from respiratory or circulatory insufficiency or decompression illness.[10] Techniques for correct implementation of first aid and oxygen administration are well described elsewhere.[11] Despite all of the described beneficial physiological effects of administering high flow oxygen, this practice was rarely performed in our case series.

IMPROVEMENTS AND VALIDITY OF DATA

When a fatal diving injury is unwitnessed or the report of the diving injury is incomplete, it is difficult to determine the exact sequence of events and the actual cause of death. In such cases, we have avoided speculation and present only data that were found in the case reports. This means that some data might be underreported when notified as ‘not specified’. Although this report includes only data made available through reasonable effort, we have obtained full reports, including technical investigations and autopsies in almost all cases where these were performed. However, the reliability of these data might be discussed, because many variables are based on subjective reports. Likewise, in many cases it was obvious from interviews with witnesses that the investigator had little knowledge about diving. This was apparent through the incorrect use of terms in connection to events and equipment, and the handling of cases. In some cases, the investigator would disassemble the equipment or empty the cylinders at the scene, thereby obliterating valuable information.

As has already been emphasized by our Nordic colleagues 40 years ago, a proper investigation of a diving injury is of tremendous importance for the prevention of future mishaps.[2] According to Danish regulations, any death classified as a diving injury should be followed by a forensic autopsy and CT scans have been an obligatory element in this since 2006. Unfortunately in our study this radiographic modality was not applied promptly as recommended in order to reveal information on barotrauma, but instead both the autposy and the CT scan were delayed by hours or even days.

Not all deceased divers in our study had a post-mortem examination performed. Likewise, some autopsies were not performed by forensic pathologists knowledgeable about diving, so important information was lost. Even when a careful, timely autopsy is performed, it cannot always reveal the primary event that has taken place. An example of such a primary event is immersion pulmonary oedema.[12,13] The autopsy findings are very similar to drowning, and diagnosis requires the presence of reliable witnesses that can report on the likelihood or not of primary aspiration of water during the fatal dive. A forensic pathologist with no specific knowledge about diving physiology and conditions would most likely overlook this diagnosis when observing airways obstructed with frothy sputum on autopsy.

In order to improve future scientific investigation of fatal dives and individual diving fatality investigation, the investigators should possess expert skills and knowledge of diving and a systematic investigation guideline would be desirable.[14]

Conclusion

This study shows that many Danish diving fatalities could have been avoided if adequate safety procedures and diving skills had been initiated. Lack of familiarity with drysuit diving, lack of a good buddy system and mismanagement of weights were important contributors to diving injuries. Our data indicate that there might be an increased risk of diving with a higher BMI; conversely, people with higher BMI may be more likely to participate in diving in Denmark. Interventions that might reduce fatalities in the future include a focus on health maintenance and physical fitness, better training of establishing positive buoyancy and effective first aid of a distressed diver. Lastly, proper investigation of diving fatalities, including informed witness questioning and expert autopsy is desirable for the understanding and prevention of future casualties.

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