Austin Sports Medicine

Open Access

Austin Publishing Group

Research Article

Fatal Diving Accidents in Alpine Waters: A Series of Triggers Leading to Disaster?

Pacher A[1], Cleveland S[2], Muth T[3] and Schipke JD[4]*

[1]Legally Sworn Expert for Diving Issues, Unterach am Attersee, Austria

[2]Institute of Neuro and Sensory Physiology, Heinrich Heine Universität Düsseldorf, Germany

[3]Institute of Occupational and Social Medicine, Center for Health and Society, Medical Faculty, Heinrich-Heine-Universität Düsseldorf, Germany

[4]EFESC Research Group Experimental Surgery, University Hospital Düsseldorf, Germany

***Corresponding author:** Schipke JD, eFESC Research Group, Experimental Surgery, University Hospital Düsseldorf, Germany

Received: May 09, 2017; **Accepted:** June 01, 2017; **Published:** June 08, 2017

Abstract

Scuba diving fatalities during the descent are rare. We present a case series on nine such fatalities. All dives lead to great depth of ≥60m. Common to all dives was an attempt to ascend already after 10±3 min during the descent. The ascent, however failed in all but of two of the cases. In these two cases, the divers arrived at the surface but were dead. All of the victims had drowned. Death ensued 14±3 min after the onset of the dive

We suggest that a chain of triggers before or during the descent had occurred, each of which added to the ever-increasing stress. It is a tragic sign of insufficient experience that all of these divers died wearing their weights. Recall that prompt and correct reactions can be delayed/lacking due to the oxygen-induced restricted manual dexterity and reduced cognitive performance. Cognitive performance at such great depths will, on the other hand, be considerably impaired by narcotic effects of nitrogen. To circumvent the build-up of life-threatening stress due to a series of triggers, a descent stop at 5m is recommended to ‘unload’ stress, similar to the safety stop while ascending to unload nitrogen. The duration of the descent stop might vary and should last until stress is greatly reduced. It is further recommended to stop every 10m, in case a new trigger has become active and needs proper response. Finally, regular problem solving exercises will reduce stress in a worst case scenario.

Keywords: Scuba diving; Stress; Cold; Icing; Experience

Introduction

Diving in Alpine waters has its own charm. A typical Austrian mountain lake suited for diving would be located at an altitude of 500m and above. According to American standards altitude diving starts at a height of ≥300m, where different decompression rules must be respected [1]. The Austrian mountain lakes would have surface water temperatures close to 20°C in summer and good visibility. Because of the altitude and the relatively low water temperature at greater depths, these lakes also pose their own risks.

After some severe accidents, a few Austrian diving centers founded a working group to improve diving safety (the Working Group Diving Austria) by developing rules and supervising them. Andreas Pacher (AP), a dive instructor, was one of the initiators of that project. Nevertheless, a series of 34 diving fatalities happened between 1996 and 2009. Of these fatalities, 23 were analyzed by AP, who is a court-certified expert in diving accidents. AP’s particular attention was directed on whether the accidents had some points in common.

Here, nine of the 23 cases are presented that happened during descent and for which computer profiles of the dives existed. In addition, some similar cases are presented that were found after an intense literature search.

Methods

Twenty three computer profiles were analyzed for particular characteristics. Age and gender of the decedents were assessed. Unfortunately, additional demographic data like body mass index, smoking habits, physical fitness or medical issues were either no longer accessible or confidential. Among the diving specific data breathing gas, state of the dive equipment and type of suit were assessed.

In addition, a literature search was done using the Pub Med database, supplemented by secondary search through screening references of obtained hits, Web sites of diving sport associations or reports on fatalities during scuba diving. Hits in English, French and German were accepted.

Results

All decedents were males aged 35±7 years (mean standard deviation). None of the divers was a local but they had travelled from distant places, as Germany, Czechia and Poland, i.e. from lower-lying regions. The divers were experienced, with the number of dives varying from 200 to 5.000.

Nine of the 23 dives exhibited similar profiles (Figure 1). The other 18 cases with different profiles are not presented in this cases series. While descending the divers attempted at least once to ascend but failed. They were found dead at the bottom with the exemption of divers ‘1’ and ‘2’, who were found dead on the surface.

All divers but one breathed air and wore dry suits. As these divers came to a mountain lake to perform rather deep dives, the dive depths were carefully planned to reach to 40m or 50m or more. The actual maximum depth averaged 66±15 m (range: 40m to 85m). The average

Schipke et al. © All rights are reserved

Citation: Pacher A, Cleveland S, Muth T and Schipke JD. Fatal Diving Accidents in Alpine Waters: A Series of Triggers Leading to Disaster?. Austin Sports Med. 2017; 2(1): 1014.

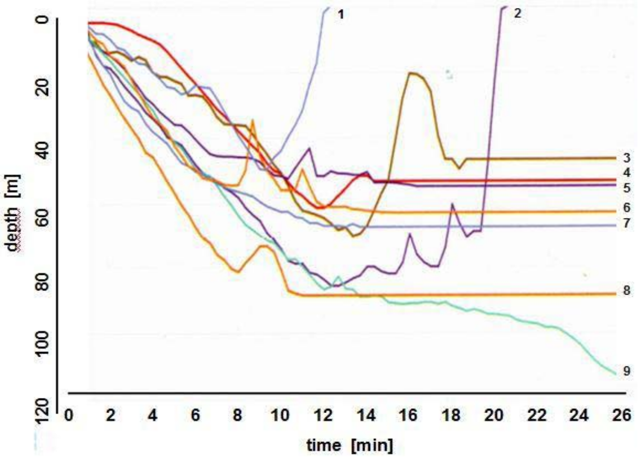

Figure 1: Typical profiles of nine independent, fatal accidents of air divers. Note that in all dives except cases '1' and '2' an early but discontinued ascent was attempted.

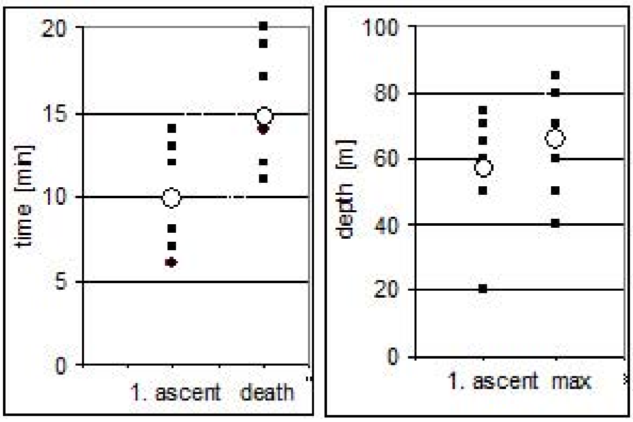

Figure 2: left: First attempt to ascent was performed after 10 min and death ensued after 14 min. right: The first attempt to ascent was started in 57m and death occurred in a depth of 66 m. open circles: means of nine divers

depth at which the first attempt to ascend was made was 57±17 m, reached after some 10±3 min (Figure 2). Death ensued 14±3 min after the onset of the dive (Figure 2).

Only nine more comparable cases resulted from the literature search. In one short communication, one case of male diver was described who also attempted to ascend after descending [2]. A report from Croatia describes the death of two divers who lost consciousness during the descent and drowned, while two others became unconscious while on depth [3]. Finally, four other cases were found in a documentation of a German advanced training course on 'Problem Solving During Diving' [4]. As all these cases did not take place at altitude, they were not taken into further consideration.

Discussion

The major finding of this survey is that the dive descent as a source of accidents is too often ignored. Inter alia, the descent necessitates multiple adjustments to the aquatic environment owing to loss of gravitation, different breathing pattern, cold, altered perception of light and sound, increasing pressure, and dependency on functioning dive gear.

We hypothesised that in spite of all nine divers keeping within recommended descent rates of 10m/min (DIR Explorers, 2017), one or more of the below triggers will have induced stress incapacitating the diver and rendering it impossible for them to complete an ascent.

Fatalities

Yearly death rates due to recreational diving, due to motor vehicle accidents and due to jogging are comparable, 16 per 100.000, 15 per 100.000 and 13 per 100.000 participants per year in the US, respectively [5]. These rates are within the range where reduction is desirable by criteria of the Health and Safety Executive [6]. In the Annual Diving Report of the Divers Alert Network (DAN) for the years 2010-2013, fatalities during the different phases of a dive are presented: 18 fatalities during the descent/early dive, 111 at the bottom, and 20 during the ascent [7]. Thus, within those four years, 12% of the fatalities occurred in an early dive phase.

In the following we discuss risk factors and identify triggers that might have individually contributed to increasing stress leading to the fatal outcomes of these recreational dives.

Age, Gender and BMI

The age of the divers plays a role, as older divers are at greater risk than younger divers [8]. The risk of suffering a diving accident increases by a factor of 13 in divers ≥50 years if the accident was caused by cardiac problems [5]. A Japanese study describes that divers from 1982 to 1995 were on average 35years old. Divers between 1995 and 2007 were 10 years older. In the earlier period 13% of the subjects died, while in the later period the proportion had increased to 40% who died from pre-existing conditions [9]. The nine divers in this study had a mean age of 35±7 years, and thus did not belong to the older divers.

The victims of all nine fatalities reported here were men. This finding is in good harmony with reports from the 1990's, in which one in ten fatalities was a woman. More recently, females accounted for 20% of the deaths, suggesting that they are still the safer divers [10]. This outcome can at least in part be explained as a result of women adhering more closely to the rules of safe diving than men, who in turn are liable to risky behaviour during the dive [11,12].

Body mass index (BMI) was not available in this study. In two of our own open water studies on male divers from Central Europe, the average BMI was somewhat elevated to 26kg•m^{-2} in 72 male divers [13] and to 27kg•m^{-2} in 25 other male divers [14].

On the basis of the Centers for Disease Control classifications, only 17% of dive fatalities happened to divers with a BMI classified as normal (18.5-24.9 kg•m^{-2}): In turn, more than 80% of the divers were classified either as overweight (25.0-29.9 kg•m^{-2}) or as obese (30.0-39.9 kg•m^{-2}) [7]. Thus, obesity is associated with an increased risk of dying while scuba diving. On the basis of this observation, it could be argued that most of the fatal accidents in the Alpine lakes are likely to have happened to somewhat overweight divers.

Series of triggers

We suggest that the fatalities were the result of no one cause, but rather were preceded by two or even more triggers (Figure 3). With each new trigger, the diver's stress increased. At the end of

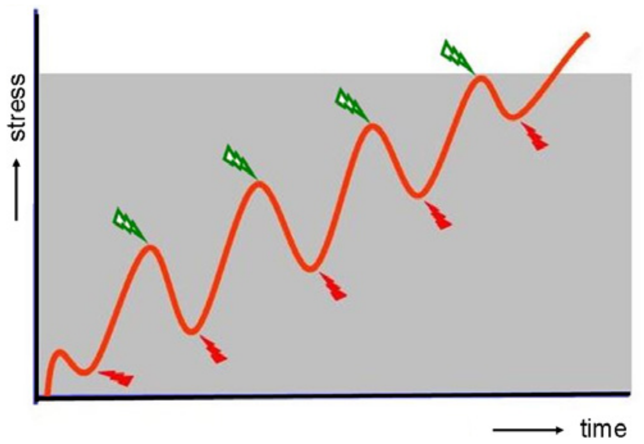

Figure 3: Early after the onset of the dive, a trigger increases stress to the diver (red arrow). Over time, stress will decrease to a certain extent, after the diver appropriately responded to the trigger (green arrows). Nevertheless, later triggers might add to an elevated stress level. If during the descent too many triggers sum up, the diver might become incapacitated to properly respond.

such a series, a panic reaction might result. Hence, we agree with the notion that 'the majority of injuries in scuba-divers is attributable to inappropriate behaviour under stressful diving conditions, predominantly involving panic reactions emerging from elevated levels of anxiety' [15].

Pre-dive triggers

All nine decedents had travelled considerable distances to practice diving in the mountain lakes. If they had arrived the day before the dive, they had time to adapt to the altitude. Otherwise, they would have been oversaturated and prone to undergo decompression sickness that could have developed post dive.

In-water triggers

Dry suits: Eight of the nine divers were wearing dry suits which satisfactorily protect the entire body from heat loss except for the head and the hands. In general, dry suits impair mobility and need more weights for compensation than wet suits. Buoyancy problems with dry suits might arise from lack of practice, as either the jacket or the dry suit or both together could be used to adapt to the ambient pressure. Independent from the type of suit, manual dexterity is impaired owing to thick gloves.

Pulmonary edema: Once the diver has entered the water, serious triggers are encountered. Due to the buoyancy blood is shifted towards the thorax. As one result, blood pressure in the pulmonary capillaries increases. In the worst case, pulmonary edema, e.g. manifested by dyspnea, will develop [16,17]. While constitutional factors also might have contributed to pulmonary edema, most of the cases occurred in cold water [18].

Pulmonary resistance: Apart from factors that increase stress, such as increased resistance to movement, added weight and drag of diving equipment during the descent, breathing resistance is also elevated [19, 20]. Even wearing a full face mask does not prevent airway narrowing [21]. One study suggests that airway resistance increases secondary to increased breathing gas density, thereby increasing the work and energy cost of breathing as the diver descends [22]. The

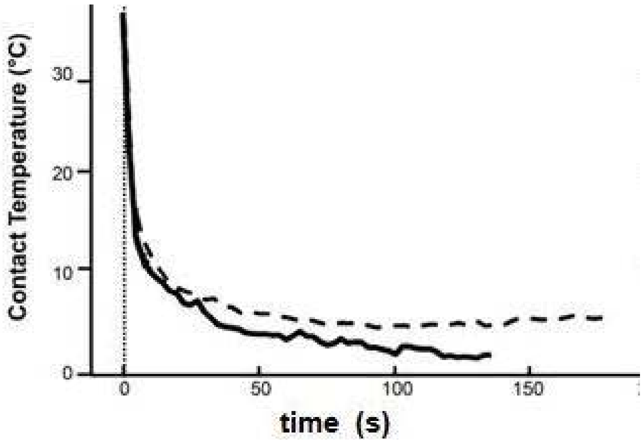

Figure 4: The skin of the face will become cold within a few seconds independent from blood vessels being occluded (continuous line) or vasodilated (dashed line) [31].

adverse effects of both cold and depth on pulmonary function have been described in another study [23]. Note that the air breathed during scuba diving is cold and dry, factors that further increase airway resistance [24].

Equalizing: The increased ambient pressure necessitates equalizing not only the middle ears and sinuses but also the mask. A diver absorbed by equalizing problems may sometimes face difficulties keeping the dive buddy within reach. In case equalizing fails, a middle ear barotrauma of descent might result, inducing disorientation and vertigo [25]. Severe pain may develop owing to dysfunctional ostia of the sinuses [26]. Such pain will induce stress but sometimes will be ignored due to peer pressure.

Cold stress: While diving deeper, it will get darker, although vision will remain excellent in most mountain lakes. In addition, water gets colder. In the Alpine lakes, temperatures below 15m vary in general between 4 and 6 °C even in summer [27].

Using a dry suit, the unprotected face is exposed to cold water, and facial skin temperature will drop within a few seconds to the ambient water temperature (Figure 4) [28]. Wearing a full face mask appears to reduce the cold sensation and could enhance the well-being of the diver [21], in particular within the first minutes of descending while thermal receptors adapt. On the other hand, cold stress to the face provokes a significant increase in ventilation by about 50% [29].

The diver's hands are better protected than the face but still will become considerably colder. Thus, loss of manual dexterity will be intensified by cold. In spite of the thermal protection, core temperature also decreases. If, for example, rectal temperature was decreased by 1.1°C in water at 5°C, manual dexterity was considerably decreased as a result [30]. The diver, realizing that delicate manual operations are considerably restricted, will perceive significant stress.

In spite of adequate undergarments, cold water will bring about vasoconstriction in skin, subcutaneous tissues and muscle, thus decreasing temperature in these tissues which in turn will make the dive uncomfortable over time. As another result of vasoconstriction, blood will be centralized, thus additionally increasing pressure in the pulmonary capillaries.

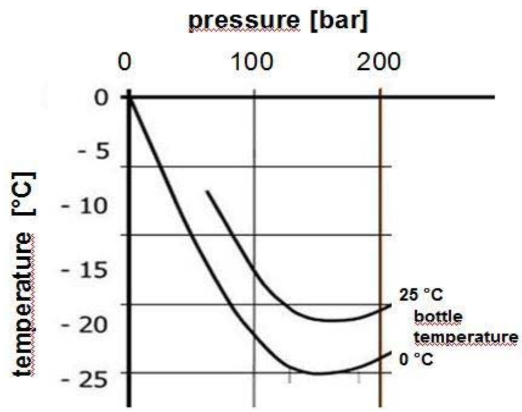

Figure 5: According to the Joule-Thomson effect, breathing gas temperature drops if the gas flows through a narrowing. At relatively high pressures – about 150 bar – the drop in temperature reaches a maximum, thus making icing of the regulator in cold water likely.

Depth per se may further contribute to increased heat loss if compressible suits are worn, since increasing pressure compresses the insulating material and thereby increases thermal conductivity [31]. As specific example, the thermal conductivity of a neoprene foam suit at 40m is roughly twice as high as on the surface, thus increasing body heat loss [32].

Quite another effect of cold stress needs mentioning: In addition to physiological responses, cognitive performance is greatly reduced in cold water [33], including memory and awareness. Their deterioration can occur rapidly upon cold water immersion [30].

Cooling of breathing gas: In scuba diving, instantaneous gas pressure in the cylinder is monitored to estimate breathing gas consumption. Due to heat transfer between the cylinder and the water during the descent, the pressure can drop considerably after the cylinder is immersed in water colder than the surface temperature, although the actual mass of the gas within the cylinder does not decrease. Unfortunately, the diver might feel stressed by misinterpreting the rapid pressure drop as a sign of high breathing gas consumption. It is suggested that algorithms correcting for such cold induced changes could be used for reconstruction of fatalities and should be implemented in dive computers [34].

Icing of breathing gas: Diving in mountain lakes attracts more and more divers. In consequence, the bigger dive organizations provide training documents that inform on features of altitude diving like reduced ambient pressure that have an impact on the ascent. Low water temperatures are also mentioned but only little information is provided on the risk of icing of the regulator. As a consequence, nearly all serious accidents of divers in mountain lakes were caused by iced scuba regulators [27]. It was one of AP's negative findings that quite a few regulators were in a surprisingly poor state. In a similar vein, deficiency of dive equipment care has been reported to be one of three major causes of diving fatalities [2]. Note that after icing a valve in the regulator remains open such that air flows continuously and rapidly out of the cylinder.

Icing of the regulator can be explained by the Joule-Thomson effect, which describes the temperature change of a non-ideal gas when it is forced through a valve or a filter. While in the water, pressurized air from the cylinder is reduced in a first stage that is mounted on the cylinder. The resulting temperature decrease of the breathing gas depends sensitively on the pressure in the cylinder (Figure 5). The maximum fall in temperature equals 25°C and takes place at rather high pressures of around 150bar, i.e. in the early phase of the dive.

Frequently, the cylinders are filled to 200bar before the onset of the dive. During the descent, the cylinder pressure can drop relatively quickly, as the diver will to a certain extent hyperventilate after submersion, in particular in cold water. Diving deeper, the flow rate will increase with increasing depth. Given the maximum depth of about 60m (=7 bar) in the nine reported cases, gas flow will have increased by a factor of seven. Gas flow through the first stage of the regulator will additionally increase, as buoyancy should be maintained neutral at every depth via regularly inflating the stability jacket (Figure 5).

After icing, breathing gas freely flows through the second stage of the regulator presenting a major problem even for the experienced diver. If the problem is not solved, the continuing noise of the bubble stream and the knowledge that one will quickly run out of air, exerts considerable stress.

Analyzing the breathing gas quality of the deceased divers, AP frequently found that its humidity exceeded the standards. During expansion water might freeze on the sinter filter and thus impair the release of air from the cylinder. Thus, the diver might notice a sudden increase in respiratory resistance or think he has run out of air.

Breathing gas partial pressures: To all the stresses mentioned so far one must add those due to increased partial pressures of both oxygen and nitrogen [20].

Oxygen: Depending on pressure and duration of exposure, oxidative stress can induce acute neurotoxicity with generalized seizures [35,36]. Thus, central nervous system oxygen toxicity is a limiting factor in diving activities. An earlier study sought to define safe -exposure limits for O_2. For example, using closed-circuit oxygen equipment, a 10-min dive time seemed safe at a depth of 15m for young male US Navy divers [37]. Thus, for this relatively short exposure a pO_2 of 2.5bar seems tolerable before convulsions will occur.

According to an internet glossary, pO_2 should not exceed 1.6bar to prevent seizures. Using normal air, this pO_2 prevails at a depth of roughly 66m. To stay on the safe side, a pO_2 of 1.4bar (~55m) is recommended (Lang, 2001). An example is given: An experienced diver using an inappropriate 50% oxygen/nitrogen gas mixture drowned after a generalized seizure during a 19-minute dive to 47m [38]. At that depth, pO_2 amounts to 2.7bar.

Recall that the median depth of the nine divers was 60m (pO_2~1.5 bar) that was reached after a median time of 10 min. However, three of the divers ('2', '8', and '9') had reached depths of about 80m. Because diver '9' performed an only very small attempt to ascend, it can be speculated that he was hit by sudden seizures after the 12-min descent to a depth at which the pO_2 was close to 1.9bar.

Nitrogen: Stress during the descent also includes increased nitrogen partial pressures (pN_2) (Doubt, 1996). Thus, not only cold but also an increased pN_2 can impair cognitive performance [39,40], particularly if pN_2 exceeds 4.0 bar [41]. Of note, narcotic effects can also be demonstrated at shallower depths [42]. As with the reaction to alcohol [43] there is no all-or-nothing reaction but adverse effects increase continuously with depth.

Increased pN_2 impairs cognitive abilities such as executive functions, intellectual performance, short-term memory, alertness [13,14], and reaction times to optical and acoustical signals [44]. As a consequence of nitrogen narcosis, strategies for dealing with a danger may be impaired or even disabled [44].

Thus, in our nine cases, nitrogen narcosis might have partly or entirely incapacitated the divers to properly react towards prior perceived stresses. Note that the affected diver is not necessarily aware of the effects of N_2 narcosis [45].

Ascent attempts

In all 9 of the cases presented here, the divers had undertaken more or less extensive attempts to ascend. Cases '1' and '2' (Figure 1) ascended completely but were found dead at the surface.

Why didn't the other divers manage to ascend? One possible reason might be related to impaired cognitive performance induced by both cold and nitrogen narcosis. As a result, appropriate reactions were delayed or not undertaken at all. For example, inflating the stability jacket or the dry suit would have been sensible, if air supply were sufficient. Breathing in and simultaneously correcting buoyancy at a depth of 60m might ice the regulator and stop air flow, something a clear-headed diver would avoid doing.

Another cause could be owing to too much weight on the diver. If only using the jacket with a common air capacity of about 20 l, the positive buoyancy could be insufficient to achieve positive buoyancy or initiate the ascent. To illustrate: One of the cases was a dive instructor with 5.000 dives who was found with a total of 20kg on his weight belt. It is noteworthy that all victims in this case series were found with their weight belts on, a finding in good agreement with the literature, in which 90% of the decedents were found wearing their weights [46].

It should be emphasized that negative buoyancy per se is not extremely serious because it can be overcome by powerful use of the fins. Yet, it might well be that the victims had almost 'forgotten' to employ them. On the one hand, quite a few divers are physically unfit [47]. On the other hand, blood flow in the skeletal muscles is reduced in the cold, thereby decreasing maximal exercise performance [48], and facilitating the generation of cramps.

Conclusion

Air dives to depths deeper than 40m are considered a hazardous behaviour and should be avoided. Appropriate breathing gases should be used to keep away from the narcotic nitrogen effects that impair both manual dexterity and reduce cognitive performance. To circumvent the build-up of life-threatening stress due to a series of triggers, a descent stop at 5m is recommended to 'unload' stress, similar to the safety stop while ascending to unload nitrogen. The duration of the descent stop might vary and should last until stress is greatly reduced. It is further recommended to stop every 10m, in case a new trigger has become active and needs proper response. Finally, regular problem solving exercises will reduce stress in a worst case scenario.

References

1. Morris R, Berthold R & Cabrol N. Diving at Extreme Altitude. In Dive Planning and Execution During the 2006 High Lakes Science Expedition. Dauphin Island, Al. 2007.
2. Luderwald S and Zinka B. Fatal diving accidents: two case reports and an overview of the role of forensic examinations. Forensic Science International. 2008; 180: 1-5.
3. Definis-Gojanovic M, Breskovic T, Sutlovic D & Petri N. Divers' deaths in Split-Dalmatian County, Croatia (cases study, 1994-2004). International Maritime Health. 2007; 58: 139–148.
4. Ostheimer F. VDST Spezialkurs Problemlösungen beim Tauchen. 2014.
5. 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.
6. Health and Safety Executive. HSE and Diving. 2006.
7. Trout BM, Caruso JL, Nelson C, Denoble PJ, Nord DA, Chimiak J, Kojima Y. DAN Annual Diving Report 2012-2015 Edition: A report on 2010-2013 data on diving fatalities, injuries, and incidents. (P. Buzzacott, Ed.). Durham (NC): Divers Alert Network. 2015.
8. Vann R & Lang M. Recreational diving fatalities. Undersea & Hyperbaric Medicine: Journal of the Undersea and Hyperbaric Medical Society, Inc. 2011; 38: 257–260.
9. Ihama Y, Miyazaki T, Fuke C, Mukai T, Ohno Y, & Sato Y. Scuba-diving related deaths in Okinawa, Japan, from 1982 to 2007. Legal Medicine (Tokyo, Japan). 2008; 10: 119–124.
10. Edmonds C & Caruso J. Diving fatality investigations: recent changes. Diving and Hyperbaric Medicine. 2014; 44: 91–96.
11. Hagberg M & Ornhagen H. Incidence and risk factors for symptoms of decompression sickness among male and female dive masters and instructors--a retrospective cohort study. Undersea & Hyperbaric Medicine. 2003; 30: 93–102.
12. St Leger Dowse M, Bryson P, Gunby A & Fife W. Comparative data from 2250 male and female sports divers: diving patterns and decompression sickness. Aviation, Space, and Environmental Medicine. 2002; 73: 743–749.
13. Brebeck AK, Schmitz-Pfeiffer H & Schipke JD. Cognitive performance during scuba diving using O_2-enriched air. In 37. Annual Meeting of the EUBS (p. 26). Gdansk, PL. 2011.
14. Zenske A, Kähler W, Koch A, Stirban A, Krüll M & Schipke JD. Is nitrox dangerous for the recreational diver? In 42. Annual Scientific Meeting of the EUBS (p. 32). Geneva. 2016.
15. Anegg U, Dietmaier G, Maier A, Tomaselli F, Gabor S, et al. Stress-induced hormonal and mood responses in scuba divers: a field study. Life Sciences. 2002; 70: 2721–2734.
16. Pons M, Blickenstorfer D, Oechslin E, Hold G, et al. Pulmonary oedema in healthy persons during scuba-diving and swimming. The European Respiratory Journal. 1995; 8: 762–767.
17. Slade JBJ, Hattori T, Ray CS, Bove AA & Cianci P. Pulmonary edema associated with scuba diving: case reports and review. Chest. 2001; 120: 1686–1694.
18. Cochard G, Arvieux J, Lacour JM, Madouas G, et al. Pulmonary edema in scuba divers: recurrence and fatal outcome. Undersea & Hyperbaric Medicine: Journal of the Undersea and Hyperbaric Medical Society, Inc. 2005; 32: 39–44.
19. Biersner RJ. Motor and cognitive effects of cold water immersion under hyperbaric conditions. Human Factors. 1976; 18: 299–304.
20. Doubt TJ. Cardiovascular and thermal responses to SCUBA diving. Medicine and Science in Sports and Exercise. 1996; 28: 581–586.

21. Uhlig F, Muth CM, Tetzlaff K, Koch A, Leberle R, et al. Lung function after cold-water dives with a standard scuba regulator or full-face-mask during wintertime. Diving and Hyperbaric Medicine. 2014; 44: 70–73.

22. Held HE & Pendergast DR. Relative effects of submersion and increased pressure on respiratory mechanics, work, and energy cost of breathing. Journal of Applied Physiology (Bethesda, Md. : 1985). 2013; 114: 578–591.

23. Tetzlaff K, Friege L, Koch A, Heine L, Neubauer B, Struck N & Mutzbauer TS. Effects of ambient cold and depth on lung function in humans after a single scuba dive. European Journal of Applied Physiology. 2001; 85: 125–129.

24. Ronnestad I, Thorsen E, Segadal K & Hope A. Bronchial response to breathing dry gas at 3.7MPa ambient pressure. European Journal of Applied Physiology and Occupational Physiology. 1994; 69: 32–35.

25. Edmonds C & Blackwood FA. Disorientation with middle ear barotrauma of descent. Undersea Biomedical Research. 1975; 2: 311–314.

26. Cheshire WP. Headache and facial pain in scuba divers. Current Pain and Headache Reports. 2004; 8: 315–320.

27. Hothorn T & Ulmer HV. Danger of icing of the scuba regulator – a neglected risk while diving in mountain lakes. In 4th international Symposium: Bohinjska Bela (Slovenia). 2009.

28. Jay O & Havenith G. Differences in finger skin contact cooling response between an arterial occlusion and a vasodilated condition. Journal of Applied Physiology (Bethesda, Md: 1985). 2006; 100: 1596–1601.

29. Jay O, Christensen JPH & White MD. Human face-only immersion in cold water reduces maximal apnoeic times and stimulates ventilation. Experimental Physiology. 2007; 92: 197–206.

30. Davis FM, Baddeley AD & Hancock TR. Diver performance: the effect of cold. Undersea Biomedical Research. 1975; 2: 195–213.

31. Bardy E, Mollendorf J & Pendergast D. A comparison of the thermal resistance of a foam neoprene wetsuit to a wetsuit fabricated from aerogel-syntactic foam hybrid insulation. Journal of Physics D: Applied Physics. 2006; 39: 4068.

32. Berndt D. Wärmeenergieverlust und Kälteschutz beim Tauchen. Caisson. 2011; 26: 4–10.

33. Solianik R, Skurvydas A, Urboniene D, Eimantas N, et al. Similar cold stress induces sex-specific neuroendocrine and working memory responses. Cryo Letters. 2015; 36: 120–127.

34. Schellart NA & Le Pechon JC. Correction for adiabatic effects in the calculated instantaneous gas consumption of scuba divers. Diving and Hyperbaric Medicine. 2015; 45: 221–227.

35. Jenkinson SG. Oxygen toxicity. New Horizons (Baltimore). 1993; 1: 504–511.

36. Koch AE, Koch I, Kowalski J, Schipke JD, et al. Physical exercise might influence the risk of oxygen-induced acute neurotoxicity. Undersea & Hyperbaric Medicine: Journal of the Undersea and Hyperbaric Medical Society, Inc. 2013; 40: 155–163.

37. Butler FKJ & Thalmann ED. Central nervous system oxygen toxicity in closed circuit scuba divers II. Undersea Biomedical Research. 1986; 13: 193–223.

38. Lawrence CH. A diving fatality due to oxygen toxicity during a “technical” dive. The Medical Journal of Australia. 1996; 165: 262–263.

39. Balestra C, Lafere P & Germonpre P. Persistence of critical flicker fusion frequency impairment after a 33 mfw SCUBA dive: evidence of prolonged nitrogen narcosis?. European Journal of Applied Physiology. 2012; 112: 4063–4068.

40. Williamson AM, Clarke B & Edmonds CW. The influence of diving variables on perceptual and cognitive functions in professional shallow-water (abalone) divers. Environmental Research. 1989; 50: 93–102.

41. Davis FM, Osborne JP, Baddeley AD & Graham IM. Diver performance: nitrogen narcosis and anxiety. Aerospace Medicine. 1972; 43: 1079–1082.

42. Hobbs, Malcolm, Higham PA, Kneller W. Memory and meta cognition in dangerous situations: investigating cognitive impairment from gas narcosis in undersea divers. Human Factors. 2014; 56: 696–709.

43. Hobbs M. Subjective and behavioral responses to nitrogen narcosis and alcohol. Undersea & Hyperbaric Medicine : Journal of the Undersea and Hyperbaric Medical Society, Inc. 2008; 35: 175–184.

44. Germonpre P, Balestra C, Hemelryck W, Rozloznik M & Lafere P. Measurement of cognitive performance and fatigue following 0.4 MPa dry chamber dives breathing air or enriched air nitrox. CAISSON. 2014; 29: 77.

45. Klingmann C & Tetzlaff K. Moderne Tauchmedizin: mit 46 Tabellen; [Handbuch für Tauchlehrer, Taucher und Ärzte] (aktualisierter Nachdr). Stuttgart: Gentner. 2009.

46. Edmonds C, Thomas B, McKenzie B & Pennefather J. Why Divers Die. In Diving Medicine for Scuba Divers. JL Publications. 1997.

47. Scuba Diving. Retrieved. 2017.

48. Pendergast DR & Lundgren CEG. The underwater environment: cardiopulmonary, thermal, and energetic demands. Journal of Applied Physiology (Bethesda, Md. : 1985). 2009; 106: 276–283.

Austin Sports Med - Volume 2 Issue 1 - 2017
Submit your Manuscript | www.austinpublishinggroup.com
Schipke et al. © All rights reserved

Citation: Pacher A, Cleveland S, Muth T and Schipke JD. Fatal Diving Accidents in Alpine Waters: A Series of Triggers Leading to Disaster?. Austin Sports Med. 2017; 2(1): 1014.