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Health-Related Adverse Events and Associated Factors in Recreational Divers With Different Certification Levels

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Background. There is a paucity of research on diving-related health issues and associated factors. This study aimed to examine the health problems encountered during diving and to ascertain the factors associated with adverse events.
Methods. The sample of this descriptive study consisted of 132 recreational divers from diving schools in Ankara. The researchers collected the data using a questionnaire developed according to the relevant literature.
Results. Diving-related health issues including barotraumas, nitrogen narcosis, and decompression sickness were mostly dependent on depth. The divers with higher certification levels witnessed diving-related adverse events more frequently and a significant increase in health problems with greater depth attained ($p < 0.05$). More experienced divers with longer duration of diving ($p < 0.05$) and greater number of dives reported more health problems associated with diving between 41 and 65 m. Adverse events did not differ according to diving-related educational features ($p > 0.05$).
Conclusions. The finding implies the importance of adherence to the depth limit of 40 m for recreational divers, being a slow ascend diver, and utilization of a buddy system in order to prevent diving-related adverse events. A data recording system related to diving and regulations particularly for tourist divers in the countries attracting tourists is required.

Whilst diving-related adverse events occur at low rates, they are crucial because of the resulting serious health problems including barotraumas and decompression sickness.[1,2] In a project aimed at identifying the risks of recreational scuba, the incidence of death following scuba diving was 0.002%.[1] Considering the increasing number of divers and unreported cases, diving-related morbidity and mortality rates are quite high for a sport and recreational activity.[3] Interestingly, recent research highlighted the danger of this activity, particularly for tourists, owing to the fact that the majority of fatalities occurred among tourist divers, probably due to unfamiliar undersea conditions and equipment.[4,5] Therefore, a data-recording system related to diving and regulations particularly for tourist divers in the countries attracting tourists is required. Considering the annual rate of mortality was 3 per 1,230,000 divers in Turkey, one-third of the ratio consisted of tourist divers.[6]

The risk factors for diving-related health problems can be sorted into four categories: namely equipment failures, the risk of aquatic and underwater environment, depth and pressure, and the utilization of bad or wrong gas. Equipment failures can be divided into five major headings including regulator problems resulting in free flow or breathing resistance, filter blockage prompting the run out of gas, buoyancy control device (BCD) failure triggering over-inflation or uncontrolled ascent, weight belt failure resulting in uncontrolled ascent, and diving suit problems such as ill-fitting suit leading to blockage of blood drainage from carotid artery, and thereby inducing carotid reflex and hypotension.[7,8] The risk factors associated with aquatic and underwater environment include dangerous marine species, low underwater visibility leading to getting lost, entanglement resulting in drowning, underwater currents conducive to getting lost, and thermocline inducing hypothermia.[7,8] The risks of depth and

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pressure are associated with nitrogen narcosis and oxygen poisoning due to breathing high-density gas, and barotraumas including lung damage, and intense ear and sinus pressure. And the risk factors related to gas include wrong and bad gas usage. Wrong gas usage is based on the preference of scuba tanks containing normal air or nitrox. When not considering maximum depth during diving, wrong gas utilization leads to oxygen poisoning. The adverse events related to bad gas usage are carbon monoxide and carbon dioxide poisoning.[7,8]

Among worldwide diving-related associations, the Diving Alert Network (DAN) provides insurance and first aid training for divers, and reports diving facts and diving-related research. Accordingly, DAN reported that diving-related fatalities or injuries occur regardless of age, ability, or experience. Along with pre-dive preparations and safety precautions that should be followed in order to lower diving-related risk factors, divers' knowledge and ability to manage underwater circumstances should be improved.[9] Among the most prominent diver training organizations Professional Association of Diving Instructors (PADI), Scuba Schools International (SSI), the World Underwater Federation (CMAS), the National Association of Underwater Instructors (NAUI), and British Sub-Aqua Club (BSAC) adhered to pre-dive preparations and safety precautions during diving. Accordingly, PADI declared that pre-dive precautions include: maintaining optimum mental and physical fitness for diving; being familiar with the dive sites; using complete, well-maintained, and reliable diving equipment; and following dive briefings carefully. Among safety precautions during diving adhering to the buddy system, using a margin of safety including a means of monitoring depth and time underwater, being a SAFE (slowly ascend from every dive) diver, maintaining proper buoyancy and breathing properly throughout diving can be counted.[10] Educational requirements for being instructors and diver trainers; equipment needed in the boat and office; duty, authority, and responsibilities of divers, instructors, and institutions need to be clarified.[11] Authorized institutions regulating recreational diving and diver-training activities, such as the Ministry of Tourism and Underwater Sports Federations, should take the advisories of global standardization organizations into consideration. Defining the minimum standards for diver-training programs would be a crucial step to decrease the number of cases of injury and fatality.[12]

Besides defining minimum training and safety standards for each certification level by diving-related training organizations, the accreditation institutions–among them the World Recreational Scuba Training Council (WRSTC), European Underwater Federation (EUF), European Committee for Standardization (CEN) and International Organization for Standardization (ISO) can be mentioned–declared the standards for medical checks that a diver candidate should have prior to training in cooperation with a leading academic society in the field of diving, namely the Undersea and Hyperbaric Medical Society (UHMC).[13]

In order to comprehend the appropriate condition for safe diving, the detailed traits of divers and the factors associated with health problems during diving should be ascertained. Determining diving-related health problems and accidents is extremely important in improving precautions and assessing risk factors.[14] Therefore, the aim of the study was to examine the health problems encountered during diving and to ascertain the factors associated with diving-related adverse events. Particularly, the focus of the study was analyzing the traits of the divers prompting additional risk during diving.

Methods

This descriptive study was completed with recreational divers who dive for training and sport purposes. The study sample consisted of 132 divers, voluntarily participating in the study, from diving schools in Ankara. All divers who registered at the diving schools to attend recreational diving activities and the instructors in the schools were included in the study until the sample size reached 132 divers. The sample size was calculated on the basis of power analysis (for sample size calculation, the DAN 2008 report data,[9] in which barotrauma rate was 26%, were used). The hypothesis of this research was established with a maximum 15% error, $\alpha = 0.05$, $\beta = 0.05$, 95% power, and 5% type I error.[11,15]

The research instrument consisted of a questionnaire developed by the researchers [5,9,11,15] and was filled out in face-to-face interviews. The questionnaire was structured by dive certifications defined as level 1 and level 2 divers, dive leaders, and level 1 and level 2 instructors. In Turkey diving schools are overwhelmingly affiliated with PADI or CMAS which differ from each other in characteristics of diving certifications. Level 1 or supervised divers can dive to a maximum depth of 12 m for PADI and 18 m for CMAS under the direct supervision of a dive leader; level 2-autonomous divers can dive to a maximum depth of 18 m for PADI open water divers, 40 m for PADI advanced open water and rescue diver and for CMAS with other scuba divers of the same level; dive leader conducts any specialized recreational scuba diving activities; level 1 instructor teaches and assesses scuba students up to level 1 on their theoretical knowledge and in confined water; level 2 instructor teaches any level of scuba diver in confined water, and gains progressive experience in teaching and assessing open water surface skills.[16] The questionnaire included the following sections: first, socio-demographic variables such as age, gender, educational and marital status, occupation, income; health-related issues such as smoking, alcohol habits, presence of chronic diseases and drug use, surgical operations; and lastly a question regarding participants' level of dive certification. The data regarding health conditions, which were self-reports of the participants,

was obtained using the question of having chronic diseases diagnosed by a physician. The first section was completed by all divers regardless of certification level. After ascertaining the level of dive certification, each participant was assigned the relevant part of the questionnaire. The second section of the questionnaire was developed only for level 1 divers (beginners), the third section was for level 2 divers (advanced divers), and the fourth section was for dive leaders, level 1 and level 2 instructors. Second, third, and fourth sections contained questions regarding the traits of diving education including knowledge, skills and practices at the present certification level, the number of total dives, experience, maximum dive depth reached, and history of diving-related health events. All possible diving-related health problems according to divers' levels including mask, sinus, tooth squeezes, drowning, hypoglycemia, hypothermia, ear, eye, and pulmonary problems, cramps, barotrauma, decompression, embolism, nitrogen narcosis, carbon monoxide, and oxygen poisoning were listed and all problems explained in order to ensure standardization of the concept, and comprehension of the problem in the same way in second, third, and fourth sections such as mask squeeze (ie, eye damage due to sticking mask onto the face under excessive pressure) or hypoglycemia (ie, feelings of faintness, weakness, and tachycardia attributed to low blood glucose). The third section contained additional questions such as diving equipment used during diving. The fourth section included additional queries such as total number of divers educated or assisted.

The data were analyzed using frequency distributions, independent-samples *t*-test for comparing numeric data, and chi-squared (χ^2) analyses for qualitative variables. Statistical significance level was defined as $p < 0.05$. In the second section of the questionnaire pertaining to practicing undersea skills during basic certification level, 26 items were analyzed by division into two groups as fulfilling more than 19 items out of 26, and fewer than 18 items. In the third section of the questionnaire, 30 items regarding educational practices were classified as implementing more than 20 items and fewer than 19 items.

Ethical Consideration

The study has been reviewed and approved by the Institution's Ethical Board. Informed consent of the divers was ensured through written and verbal explanation of the purpose of the study and the confidentiality of the data.

Results

In this study, the mean age of the divers was 36 years, 71.2% were male, 53% were single, and 59.1% were college graduates. Half of the certifications were affiliated with PADI and the remaining were with CMAS. Distribution of divers considering certification levels was as follows: 55 were at basic certification level, 43 were at advanced certification level, and 34 were leader, level 1 and level 2 instructors. Regarding diving-related educational activities by certification levels, the educational traits of the divers with basic certification level ($n = 55$) were as follows: the mean hour of theoretical courses taken during diving education was 10.4 hours (minimum 2, maximum 35, and SD 5.1), 28 performed pool practice as an education activity with a mean of 3.8 hours (minimum 1, maximum 8, and SD 1.6), the mean number of educational sea diving activity was 6.9 (minimum 2, maximum 22, and SD 4.2) and the mean number of students constituting a diving group during educational diving practice was 5.4 (minimum 1, maximum 25, and SD 4.6) with a mean of 1.2 diving leader, and 1.4 level 1 instructor. Among practiced undersea skills during basic certification level, 26 ($n = 55$) divers completed implementation of 18 or less skills out of 26 items. Less practiced skills were: breathing from the regulator with failed free-flow ($n = 20$), progressing and returning in a straight line with a compass on the surface of the sea ($n = 16$), and towing a tired diver on the surface of the sea ($n = 12$). With regard to divers with advanced certification level, 28 divers ($n = 43$) practiced less than 19 educational skills out of 30 items in the sequel of basic certification level. Less completed skills were: towing an unconscious diver to the coast or boat ($n = 13$), predicting pressure changes by observing a flexible object filled with air ($n = 12$), assisting unconscious divers on the surface of the sea ($n = 11$).

An analysis of diving experience revealed that 34.1% had 1 to 5 years of diving experience. Additionally, 42.4% dived less than 20 times, and 33.3% dived to a depth between 41 and 65 m (Table 1). Investigation of divers' health status revealed that 15.2% had a chronic disease ($n = 20$). Among chronic diseases, hypothyroidism with 20% ($n = 4$), asthma with 10% ($n = 2$), and hypertension with 10% ($n = 2$) have a potential to influence health status adversely during diving. Of the divers with chronic diseases, 16 were in medical treatment including all divers with hypothyroidism, asthma, and hypertension.

Diving-related health issues occurred in 46 divers (34.8%) and these problems ranged from muscle cramps (43.5%), sinus squeeze (39.1%), middle-ear squeeze (23.9%), nitrogen narcosis (10.9%), to tooth squeeze (10.9%). Less frequently reported health issues were inner-ear squeeze (8.7%), mask squeeze (6.5%), hypoglycemia (6.5%), feeling faint due to tightness of the diving suit around the neck (6.5%), hypothermia (4.3%), eye- and vision-related problems (2.2%), decompression sickness (2.2%), carbon monoxide poisoning (2.2%), and neck/back problems (2.2%) (Figure 1). The difference between having chronic health problems and reporting health-related adverse event during diving did not reach a statistically significant level ($\chi^2 = 0.608$, $p = 0.436$). Besides,

Table 1 Descriptive characteristics of divers ($n = 132$)

Variables	*n*	%
Age, year (M ± SD 36 ± 7, minimum 22, maximum 56)		
22–30	33	25.0
31–40	63	47.7
41–50	33	25.0
51 and over	3	2.3
Sex		
Female	38	28.8
Male	94	71.2
Marital status		
Married	62	53.0
Single	70	47.0
Educational level		
High school	2	1.5
Bachelor's	78	59.1
Master's/PhD	52	39.4
Diving certification level		
Level 1 (beginner)	55	41.7
Level 2 (advanced)	43	32.5
Dive leader, level 1 (assistant instructor) and 2 instructors	34	25.8
Diving experience (years)		
Less than 1	42	31.8
1–5	45	34.1
6–10	28	21.2
11–15	11	8.4
16 and over	6	4.5
Number of dives		
20 or less	56	42.4
21–60	31	23.5
61–99	14	10.6
100 and over	31	23.5
Depth of dives (meters)		
18 or less	30	22.7
19–30	29	22.0
31–40	29	22.0
41–65	44	33.3

statistical analysis revealed that encountering diving-related health problems did not differ significantly between mean number of theoretical education ($F = 1.892$, $p = 0.836$), and practicing underwater skills at the basic certification level ($\chi^2 = 0.062$, $p = 0.804$). Similarly, for the advanced certification level, diving-related adverse events did not show statistical significance by practicing skills following basic certification level ($\chi^2 = 0.013$, $p = 0.911$).

Examination of encountering adverse events during diving by certification levels revealed that the certification levels of the divers defined witnessing other divers' experiences of adverse events although no statistical significance appeared in having diving-related health issues ($p > 0.05$, $p < 0.05$). The rate of witnessing health problems was significantly high (82.4%) at the increased certification levels including dive leaders, assistant instructors, and instructors (Table 2). Additionally, statistical analysis was performed to identify the change in experiencing health-related adverse events during diving according to total number of dives and the length of dive sport experience. Accordingly, the ratio of health-related adverse events were 25% for diving experience between 1 and 20 times, and 42% for diving more than 21 times ($\chi^2 = 3.436$, $p = 0.064$). As to the length of performing recreational dives, the statistical analysis showed significant difference ($\chi^2 = 6.438$, $p = 0.040$). Accordingly, health problems emerged at 23.8% for those with less than 1 year's experience, 31.1% for those between 2 and 5 years, and 48.9% for more than 6 years. Furthermore, those with longer diving experience (none for 1 year, 35.5% for 2–5 years, and 62.2% for >6 years) ($\chi^2 = 56.185$, $p = 0.000$) and with greater number of dives (none for 1–20 times, 57.9% for >21times) ($\chi^2 = 89.361$, $p = 0.000$) dived to significantly greater depths. As to the maximum diving depth, both variables of experiencing and witnessing diving-related health issues reached statistically significant levels ($p < 0.05$). Health problems appeared more frequently between the depths of 41 and 65 m both for experiencing (52.3%) and witnessing them (84.1%) (Table 3).

Discussion

The results revealed that 20 divers proceeded to dive despite having a chronic condition such as hypothyroidism, asthma, or hypertension; and of the divers with chronic diseases, 16 were using drugs for the diseases including hypothyroidism, asthma, and hypertension in this study. As the diseases, which had potential to impact recreational diving activity adversely such as hypothyroidism, asthma, and hypertension were under control, there was no contra-indicatory health factor to hinder diving in this study. This implication was corroborated by the finding of no statistical difference between having chronic health problems and experiencing health-related adverse events during diving in this study. According to the report published in 2008 by DAN, the rate of chronic disease in divers is 40%.[9] The European Diving Technology Committee does not warn against diving with chronic disease provided that the diseases are medically under control.[17] According to the standards set by the WRSTC, to reduce the risks of diving accidents and diving-related health problems, divers must declare that they have no health problems that prohibit them from diving, and divers with health problems must have a medical check-up before diving.[13,18] The risk which arose from this self-declaration is that pre-training self-declarations of divers can become out-of-date with subsequently diagnosed health problems.[19]

Almost half of the divers reported health-related adverse outcomes of diving predominantly due to the risk of depth and associated pressure such as sinus, middle-ear, tooth, inner-ear, mask squeezes, nitrogen narcosis, and decompression sickness in this study. The literature also emphasizes that the prevalence of depth and pressure-dependent health events during

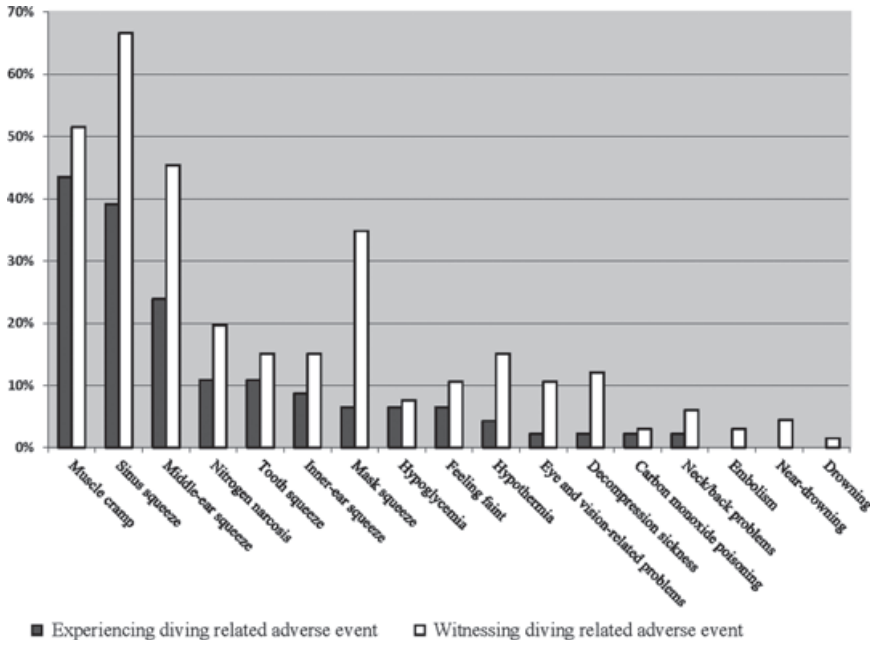

Figure 1 Health problems experienced or witnessed during dives.

Table 2 Experiencing or witnessing health problems during dives by certification levels

		Yes		No		χ^2
	Certification level	*n*	%	*n*	%	*p* Value
Experiencing a health problem	Level 1	15	27.3	40	72.7	2.782
	Level 2	16	37.2	27	62.8	0.249
	Leader, level 1 and 2 instructors	15	44.1	19	55.9	
Witnessing a health problem	Level 1	16	29.1	39	70.9	
	Level 2	22	51.2	21	48.8	23.877
	Leader, level 1 and 2 instructors	28	82.4	6	17.6	**0.000**

Bold value indicates statistically significant difference, p<0.05

Table 3 Experiencing or witnessing health problems during dives by diving depths

		Yes		No		χ^2
	Diving depth (meters)	*n*	%	*n*	%	*p* Value
Experiencing a health problem	<18	5	16.7	25	83.3	
	19–30	11	37.9	18	62.1	11.838
	31–40	7	24.1	22	75.9	**0.008**
	41–65	23	52.3	21	47.2	
Witnessing a health problem	<18	7	23.3	23	76.7	33.471
		9	31.0	20	69.0	**0.000**
		13	44.8	16	55.2	
		37	84.1	7	15.9	

Bold values indicate statistically significant difference, p<0.05

diving was high and the damages following exposure to high pressure is notable.[20,21] Owing to sinus squeeze resulting from negative pressure in the sinus cavity in the presence of acute or chronic sinusitis, divers may experience severe pain and nose bleeds.[22,23] Additionally, sinus squeeze occurring in the maxillary sinus may result in trigeminal nerve damage.[22] Middle-ear squeeze may prompt pain in the ear, hematoma in the tympanic membrane, and temporary hearing loss.[3,22,23] Middle-ear damage following diving may be prevented by the use of proper ear equalization techniques.[24] Equivalent to the ratio reported in the

literature,[25,26] a minority of divers experienced or witnessed decompression sickness in this study. Because the risk of death or morbidity in pursuit of decompression was reported as 1.3 per 100,000 dives,[27] decompression sickness should be considered seriously and all preventive efforts should be taken. Underwater precautions for reducing the health problems related to the risk of depth include monitoring depth and time, being a SAFE diver, and breathing properly throughout diving.

The utilization of proper diving attire and equipment including breathed gas from the scuba tank is crucial to prevent the risk factors associated with equipment and gas failure.[7,8] Divers expressed the problem of faintness due to tightness of the diving suit around the neck and neck/back problems probably due to inappropriate equipment use in this study. Additionally, the matter of hypothermia may be solved with the use of a proper hooded diving suit. As for the risk factors associated with utilization of bad gas, they can be eliminated by filling scuba tanks with clear and fresh air without carbon monoxide or carbon dioxide, and changing the oil and filter of the compressor regularly.[7,8]

Apart from diving-related health issues associated with the risk factors mentioned above, almost half of the divers reported problems regarding lack of pre-dive preparation including muscle cramps and hypoglycemia. Muscle cramps may lead to difficulty in movement, loss of attention, and panic, and consequently serious diving accidents, such as drowning and decompression sickness can occur.[20,28] Diving-related muscle cramps can be precluded by pre-dive stretching exercise and consuming foods high in potassium.[8,29] As for hypoglycemia, food with high glycemic index can be consumed 1 hour before a diving activity.[30]

The result that divers with higher certification levels witnessed diving-related health issues more frequently was not surprising owing to the fact that they dive with numerous novice divers. Nevertheless, this conclusion highlights the importance of a buddy system and the necessity of providing guidance to inexperienced beginner divers by high level divers. Taking dive experience into consideration including total number of dives and length of performing diving, both variables increased the ratio of encountering health problems associated with diving. The prominent inference from this result is that the increased number and experience were not protective factors against adverse health events in diving. Rather, the experienced divers were at higher risk of having health-related adverse events during diving probably due to high self-confidence and consequently increased risky behavior such as diving deeper, namely between 41 and 65 m for this study.

An inevitable connection between depth and encountering diving-related adverse event was ascertained in this study. Statistical analysis showed a particular increment in experiencing and witnessing health problems at depths between 40 and 65 m. Additionally, one-third of the divers reported exceeding the depth limit of 40 m, up to 65 m. This result highlighted the importance of abiding by the regulation of a 40 m depth limit for recreational divers. Klingmann and colleagues reported that the rate of decompression sickness positively correlated with depth.[26] As the depth is strongly associated with serious adverse situations such as decompression sickness, the precautions such as monitoring depth and being a SAFE diver should be adopted throughout the diving world.

This study concluded that divers with chronic diseases can keep diving so long as the conditions are under control. While most of the health issues in diving were dependent on depth including barotraumas, nitrogen narcosis, and decompression sickness, a minority of divers reported problems related to utilization of inappropriate equipment, such as feeling faint, neck/back problems, hypothermia, and carbon monoxide poisoning. The majority mentioned health problems related to lack of pre-dive preparations including muscle cramps and hypoglycemia. Two expected results were that divers with higher certification levels witnessed adverse events in diving more frequently and a positive relationship between depth and health problems was experienced. Educational background regarding diving did not prompt significant change in diving-related health problems. Surprisingly, the study showed that more experienced divers with greater experience and number of dives reported more health problems in diving due to diving 41 to 65 m. The finding implies the importance of adherence to the depth limit of 40 m for recreational divers, being a SAFE diver, and utilization of a buddy system in order to prevent diving-related adverse events.

Limitations

Due to utilization of face-to-face interviews in this study, the participant divers may underreport chronic health conditions and experienced health problems during the dive. Therefore, onsite observation of diving activity can be recommended for future research ascertaining the occurrence of diving-related adverse events.

Declaration of Interests

The authors state they have no conflicts of interest to declare.

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