

The Effect of Decompression Sickness during the Work of the South Korean Fire Service Water Rescue Company

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Abstract:

The purpose of this study was to investigate the relationship between the sudden rising in water level to the water surface and decompression sickness during the work of the South Korean Fire Service Water Rescue Company. The results of this study are as follows. First, the majority of water rescue team respondents have said that they have experienced a sudden ascension when trying to rescue people quickly in emergency situations. Second, because of the development of decompression sickness, the respondents experienced psychological anxiety due to poor underwater visibility during underwater searching and an increase in fatigue due to rapid ascension after underwater searching. Third, it was suggested that in order to provide efficient underwater search, it is necessary to first secure reserve members, then reinforce rescue capacity, and then supplement the rescue equipment. Fourth, there was a higher level of symptom manifestation of decompression sickness in individuals with no qualification related to water rescue compared to those with a qualification. Navigators and engineers who do not have a qualification related to water rescue have less practical experience, so they ascended at a faster speed after searching underwater than the speed of the qualified members. Finally, the degree of decompression disease symptoms according to position showed a significant difference between groups. In general, firefighters' experience in fire service water rescue teams is shorter than that of high-ranking officials, so they have a lack of diving experience and skills. Therefore, firefighters ascended faster after searching underwater than those in higher positions.

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I. Introduction

South Korea's fire service water rescue company is a water rescue team that specializes in water operations in rivers and lakes [1]. Korea's firefighting rescue team works 24/7 and is located at Cheongpyeong Lake, Paldang Lake, Soyang River, Chungju Lake, and Andong Lake, as well as the Han River in Seoul [2]. Water rescue teams quickly descend into the water in an emergency to rescue civilians, and then often rise rapidly back up

to the surface. When ascending to the surface, absorption, accumulation and discharge of nitrogen gas become inadequate and the rescue crew members may be exposed to decompression sickness [3].

Decompression sickness is an injury caused by a sudden ascension in water levels, which means that the nitrogen that is dissolved in the body tissue is not released or a nitrogen bubble is formed in the body, resulting in tissue damage [4]. Currently, the most

common and definitive treatment for decompression sickness is re-pressurization using a recompression chamber. In South Korea, there is no basis for diving site installation regulations for recompression chambers, so that many rescue workers are exposed to the potential risk of decompression [5].

As a preliminary study on decompression sickness of water rescue teams, Cha (2009) analyzed the experiences of infectious disease symptoms and the measures taken after experiencing decompression sickness for divers working in seafood collection [6]. Cho (2018) analyzed the correlation between rapid ascension and decompression sickness in scuba divers [3]. Park (2016) conducted a study on safety work for industrial divers who have a lot of experience diving at sea level [5]. However, unlike previous studies, this study was limited to Korean fire service water rescue teams and analyzed the correlation between rapid ascension and decompression sickness, which makes it relevant.

II. Data Collection and Analysis Method

The data collection for this study was conducted from April 1 to May 6, 2019, and covered all the water rescue teams nationwide, including at the Han River in Seoul, and the Soyang River in Gangwon Province, as well as in Andong in Gyeongsangbuk Province, Chungju in Chungcheongbuk Province, and Gapyeong, Yangpyeong, and Gimpo in Gyeonggi Province. A complete enumeration survey was conducted after getting an agreement to participate in in-depth interviews and in research on all the water rescue workers in the nation's rescue service. The subjects were asked to fill out a questionnaire. The contents of the questionnaire were as follows: general characteristics (sex, age, qualifications acquired, number of years of work, and whether they have secure reserve members in their team), current state of diving equipment (type of diving work and diving equipment used in the water during research), water

rescue methods (maximum depth experienced, underwater visibility, average depth, experience of sudden ascension and repeated dives), symptoms experience during underwater searches, and what could be improved regarding their work on water rescue teams. There are currently about 70 active water rescue team members in Korea, and 61 of them participated in the survey. The data collected in this study was analyzed using the SPSS WIN 20.0 program. First, the frequency and percentage were calculated to identify the general characteristics of the subjects used in the study. T-test and ANOVA were conducted to investigate the status and use of diving equipment and the degree of sudden ascension experienced during underwater rescue according to the general characteristics of the subject. The Scheffe test was additionally performed to investigate the difference between groups for the degree of manifestation of decompression sickness symptoms.

III. Research Result and Analysis

Table 1 shows the sociodemographic characteristics of the subjects, who were all male. In terms of qualification, 50.8% of the respondents had a life-saving qualification, 27.9% had a diving qualification, and 91.8% had a scuba qualification. The reason for the large number of scuba qualifications is that the scuba qualification requires only 10 hours of theoretical training, 20 hours of swimming classes, and 5 practical diving sessions in water, which makes it faster and easier to acquire than other qualifications [7]. The majority of the respondents answered that they did not have reserve members during underwater searches (77%), suggesting that most of the Korean water rescue workers are underwater without a backup team.

Table 1. Sociodemographic Characteristics of the Subjects (N=61)

Variable	Classification	Number of Cases (N)	Percentage (%)
Gender	Male	61	100.0

	Female	0	0
	Total	61	100.0
Qualification (Life-saving qualification, Level 1 and 2)	Yes	31	50.8
	No	30	49.2
	Total	61	100.0
Qualification (Diving qualification)	Yes	17	27.9
	No	44	72.1
	Total	61	100.0
Qualification (Scuba qualification)	Yes	56	91.8
	No	5	8.2
	Total	61	100.0
Qualification (other)	Yes	9	14.8
	No	52	85.2
	Total	61	100.0
Reserve Members	Yes	14	23.0
	No	47	77.0
	Total	61	100.0

Table 2 shows that the most frequent maximum depth of an underwater search experienced by divers is over 25 m, which is probably because the maximum depth of the Soyang River, Andong Lake, and Chungju Dam is over 30 m. The next most frequent maximum depths experienced were 10-14 m and 15-19. The table also shows that the majority (41%) of the respondents did not obey the recommended speed of 22 m/min when descending into the water and the speed of 9m / min when they were ascending. m. The most frequent underwater visibility at the water levels where the water rescue

team work was between 0.5 and 1 m. In addition, 95.1% of the respondents answered that they have experienced a sudden ascension in excess of 9 m/min after finding a submerged person in the water in an emergency situation. It is a principle to breathe naturally when rising in water and comply with the rising speed of 9 m/min. However, the reason for the speed of ascension exceeding 9 m/min seems to be the willingness to rescue the submerged person quickly [8].

Table 2. Experience of Sudden Ascension in Underwater Rescue Environments

Variable	Classification	Number of Cases (N)	Percentage (%)
Maximum Underwater Search Depth Experienced	5-10 m	6	9.8
	10-14 m	15	24.6
	15-19 m	15	24.6
	20-24 m	6	9.8
	Over 25 m	19	31.1
	Total	61	100.0
Obedience of recommended speed: Descending into water at 22 m/min Ascending up at 9 m/min	Kept speed thoroughly	2	3.3
	Tended to keep speed	24	39.3
	Tended to not keep speed	25	41.0
	Did not keep speed	10	16.4
	Total	61	100.0
Experienced a sudden ascension in excess of 9 m/min after discovering a submerged person in the water in an emergency situation	Yes	58	95.1
	No	3	4.9
	Total	61	100.0

According to Table 3, 91.8% of the divers have reserves, so the rescue team members needs to dive experienced repeated diving during an underwater rescue. The reason for this is that there are no repeatedly.

Table 3. Experience of Repeated Diving During Underwater Rescue

Variable	Classification	Number of Cases (N)	Percentage (%)
Repeated Diving Experience	Yes	56	91.8
	No	5	8.2
	Total	61	100.0

Table 4 shows the symptoms of decompression sickness. The most frequently experienced symptoms, in order of how frequently they were manifested, are as follows: psychological anxiety during underwater search (3.33), increased fatigue after underwater search (3.20), hypothermia due to heat loss (2.62), pain and bleeding caused by imbalanced pressure in the ear and rupture of the eardrum (2.49), pain (headache, toothache) and bleeding caused by pressure in the sinus (2.30), and dizziness after sudden ascension (2.18). The reason for the high occurrence of psychological anxiety is irritability and fear due to poor underwater visibility of less than 0.5 m [9]. Also, it is believed that physical fatigue is increased because of the burden on the body due to both the load of the diving equipment and the air and water pressure during an underwater search [10] [11].

Table 4. Manifestation of Decompression Sickness Symptoms

Variable	Number of Cases (N)	Minimum Value	Maximum Value	Average (M)	Standard Deviation (SD)
Pain and bleeding caused by imbalanced pressure in ear, Rupture of the eardrum	61	1.00	5.00	2.4918	1.36165
Pain (headache, toothache) and bleeding caused by pressure in sinus	61	1.00	5.00	2.3115	1.17673
Lack of sense of direction due to vestibular dysfunction	61	1.00	3.00	1.2951	.55810
Difficult judging distance and size by visual impairment	60	1.00	3.00	1.1500	.44436
Hypothermia due to heat loss	61	1.00	4.00	2.6230	1.14257
Psychological anxiety during underwater search	61	1.00	5.00	3.3279	.96127
Increased fatigue after underwater search	61	1.00	5.00	3.1967	.89106
Dizziness after sudden ascension	61	1.00	5.00	2,1803	1.02483
Chest pain after sudden ascension	61	1.00	4.00	1.4262	.59045

Table 5 shows that the most necessary supplementary measures for efficient underwater search was securing reserve team members (71.1%), followed by reinforcing rescue capacity (24.4%), and supplementing rescue equipment (4.4%). The Han River water rescue team has two reserve personnel, but that includes members who are there to command the team rather than dive themselves. Also, if any members are on vacation or vacancies occur, then

there is a shortage of reserve members and members need to dive repeatedly. Particularly, the rescue workers who work in Cheongpyeong Lake, Soyang River and the upper part of the Han River are most likely to have two rescue workers underwater without a reserve team. Therefore, it is necessary to secure two additional team members.

Table 5. Supplementary Measures for Efficient Underwater Search

Classification	Number of Cases (N)	Percentage (%)
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Securing Reserve Members	32	71.1
Supplementing Rescue Equipment	12	4.4
Reinforcing Rescue Capacity	11	24.4
Total	45	100.0

Table 6 shows that there were no statistically significant differences in the manifestation of infectious disease symptoms based on whether the diver had a life-saving qualification ($t=-1.511$, $P>.05$), diving qualification ($t=-.955$, $P>.05$), or scuba qualification ($t=-.245$, $P>.05$). However, in terms of all qualifications, the average degree of symptoms of decompression sickness was higher when the diver had no qualification. The reason for this is that there are maritime and aeronautical engineers included in the rescue team who have not learned the rescue

techniques to use in water, on the water surface, or on land. Often, these people participate in underwater searches as reserve members due to a shortage of personnel. Navigators, engineers and other unqualified members cannot control the speed of the buoyancy of their ascension after searching underwater due to a lack of practical experience, so the speed of the buoyancy of their ascension is faster than that of the qualified rescuers.

Table 6. Analysis of Group Differences on Symptoms of Decompression Sickness (T-test Statistics)

Variable	Classification	Number of Cases (N)	Average (Mean)	Standard Deviation (SD)	df	t Value
Manifestation of infectious disease symptoms	Life-saving qualification	31	2.25	.62	58	-1.511
	No life-saving qualification	29	2.50	.54		
	Diving qualification	17	2.24	.40	58	-.955
	No diving qualification	43	2.40	.65		
	Diving qualification	55	2.35	.57	58	-.245
	No diving qualification	5	2.42	.82		

$p^*<0.05$

In Table 7 there were no significant differences in the degree of decompression sickness symptoms

between the groups for years of work and age. Firstly, the data showed no statistically significant difference

based on the years of work of the individual ($F=.813$, $P>.05$). In particular, the group with 10-15 years of work showed the highest incidence of decompression sickness (mean = 2.61), followed by more than 15 years (mean = 2.42). Similarly within the data for different age groups, the over 50 age group showed the highest incidence of decompression sickness (mean = 2.40), but the study showed no statistically significant difference in the degree of decompression sickness symptoms by age ($F=.813$, $P>.05$). This is consistent with the study by Cha (2008) which found that there is no age-related difference in the analysis of patients with decompression sickness [12].

On the other hand, the degree of decompression sickness symptoms according to position showed

significant difference between the groups ($F = 3.50$, $P <.05$). Specifically, firefighters had an average of 3.22, showing the highest degree of decompression sickness symptoms, followed by fire lieutenants (Mean = 2.60), fire sergeants (mean = 2.23), fire captains (mean = 2.22) and, lastly, senior fire fighters (mean = 2.12). The difference according to positions is that firefighters have less than 4 years of experience in firefighting rescue teams which means they have a lack of diving experience and skill. Therefore, they are not able to control buoyancy after searching underwater and they rise up faster than those in higher positions.

Table 7. Analysis of Group Differences on Degree of Symptoms of Decompression Sickness (ANOVA & Scheffe test)

Variable	Classification	Number of Cases (N)	Average (Mean)	Standard Deviation (SD)	F	Scheffe
Years of Work	Under 5 years	16	2.22	.54	.813	na
	5-10 years	27	2.33	.54		
	11-15 years	8	2.61	.73		
	Over 15 years	9	2.42	.69		
Age	Under 40 years	20	2.30	.68		
	40-50 years	30	2.37	.51		
	Over 50	10	2.40	.68		
Position	Fire fighter	2	3.22	.32	3.50*	na
	Senior Fire Fighter	10	2.12	.60		
	Fire Sergeant	28	2.23	.46		
	Fire Lieutenant	18	2.60	.70		

	Fire Captain	2	2.22	.59		
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p* < 0.05

IV. Conclusions

South Korean Fire Service water rescue teams might inevitably experience a sudden ascension during an underwater search in order to revive a victim. The sharp increase in psychological anxiety and fatigue causes symptoms of decompression sickness. The purpose of this study was to investigate the relationship between the sudden ascension when rising up water levels and decompression sickness which occurs in the underwater rescue work of the Korean Fire Rescue Service Water Rescue Company. The results of this study are summarized as follows. First, a scuba qualification was the most common qualification for water rescue team members. The reason for the high frequency of scuba qualifications is that they are relatively easy to acquire compared to other qualifications.

Second, the majority of respondents answered that they have experienced a sudden ascension when rising up water levels in an emergency situation. This is because the rescue workers want to rescue civilians quickly and try to revive them.

Third, most of the respondents had experienced repeated diving in underwater searches. The reason for this could be because the lack of reserve members means it is inevitable that rescue team workers need to dive repeatedly.

Fourth, the manifestation of decompression sickness symptoms showed high psychological anxiety during underwater searches and an increase in fatigue after underwater searches. The poor underwater visibility of less than 0.5 m caused anxiety and panic, resulting in increased psychological anxiety. Also, it is determined that physical fatigue is increased due to the burden on the body caused by both the load of the diving equipment and the air and water pressure during water rescue work.

Fifth, in order to enable efficient underwater search, it was deemed necessary to take the following supplementary measures in this order: secure reserve members, reinforce rescue capacity, and supplement the rescue equipment. It is necessary to secure reserve members first of all. Most rescue workers have to dive repeatedly without having enough break time as they do not have any reserve members with them in their team. Therefore, since psychological anxiety and physical fatigue increase, symptoms of decompression sickness may appear, so it is necessary to secure two reserve members and get enough rest.

Sixth, the average degree of decompression sickness symptom was higher for respondents who had no qualifications related to water rescue than respondents with a qualification. The reason for this is that navigators and engineers who do not have a qualification related to water rescue have less practical experience, so when they fill in as reserve members, they ascend at a faster speed after searching underwater than the speed of the qualified members.

Finally, the degree of decompression symptoms was significantly different between the different groups. In the case of firefighters, their experience of working in fire service water rescue teams is short so they have a lack of diving experience and skills. Therefore, they ascended faster after searching underwater than higher-ranking officials.

Future research needs to propose a variety of improvements in terms of institutional, administrative, and professional aspects in order to reduce the frequency of sudden ascensions when rising up after underwater searches conducted by the Korean Fire Service Water Rescue Company.

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