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FIELD STUDY

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Diving patterns and decompression sickness among South Korean fishery divers

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Abstract

Objectives: We aimed to report the characteristics of diving practice and the incidence of decompression sickness (DCS) among South Korean fishery divers.

Methods: We sent out questionnaires to 215 registered boat owners, and 196 of the fishery divers responded. The questionnaire was comprised of demographical characteristics, diving-related characteristics, and experiences with DCS. DCS was classified into types I and II based on the symptoms.

Results: Their average length of career in fishery diving was 18.1 ± 8.5 years. They were working for 10.8 ± 1.9 months per year. The average bottom time was 74.7 ± 23.3 minutes, the average depth was 23.6 ± 6.8 m, and the average surface interval time was 20.7 ± 12.5 minutes. The incidence of DCS symptoms among the total participants was 84.7%. The incidence increased as working days per month and dives per day increased ($P < 0.05$). An increased average working depth and a short surface interval time tended to reflect an elevated incidence in the DCS symptoms ($P < 0.01$). Logistic regression analysis revealed working days per month, dives per day, average bottom time, and rapid ascent as risk factors ($P < 0.05$).

Conclusions: South Korean fishery divers were shown to be susceptible to DCS because of their repetitive dives for financial reasons. However, they are often beyond the scope of the law. The results of this study suggested that it is necessary to establish the registries of fishery divers.

KEYWORDS
decompression sickness, diving, fisheries, Republic of Korea

1 | INTRODUCTION

South Korea occupies the southern half of the Korean peninsula located in East Asia. Three sides of the country are surrounded by its 433,000-km[1] territorial sea, which is five times as large as its land. With its convoluted coastline and large continental shelf, South Korea is abundant in marine resources, such as fish and shellfish. Traditionally, breath-hold diving used to be the main method for harvesting the marine products along the seashore and islands. Nowadays, surface-supplied divers (SSDs) and self-contained underwater breathing apparatus (SCUBA) divers are harvesting as much as 3 million tons of marine products annually in Korea.[1]

The Korean government has been restricting the number of fishing boats equipped with diving paraphernalia to maintain fishery resources sustainable and, by far, sanctioned a total of 230 fishing boats with diving equipment. Commercial divers working on such fishing boats, on the other hand, are neither

registered nor regulated by the government. Therefore, the number of divers can only be estimated, ranging from 1180 to 1900.[2,3]

Breath-hold diving, SCUBA diving, and surface-supplied breathing apparatus diving are all performed by fishery divers in Korea. Hookah diving, a form of surface-supplied diving (SSD), is the most commonly practiced diving method among the Korean divers, while only a few use SCUBA.[4,5]

As divers breathe pressurized gas underwater exposed to low temperature and hyperbaric environment, they are at risk of various conditions such as hypothermia, pulmonary overinflation syndrome, barotrauma, decompression sickness (DCS), nitrogen narcosis, and oxygen toxicity. Other substantial hazards also include drowning (and near-drowning) and attacks from marine mammals.[6] The hyperbaric environment underwater oversaturates inert gases in body tissues, and when the diver ascends to the surface of the water, relatively low ambient pressure causes air bubbles in the tissue or arterial gas embolism resulting in tissue hypoxia.[7]

Epidemiologic studies on the DCS in divers have been reported in various countries. A cross-sectional study on 323 Maine lobster divers in the United States of America reported that 18.0% of the divers complained of DCS-related symptoms, and 77.7% of those were suspected of diving-related diseases such as DCS, pulmonary overpressurization, barotrauma, and nitrogen narcosis.[8] Another study conducted in Urak Lawoi region in Thailand classified as many as 59.1% of 338 divers as being at moderate-to-high risk of DCS.[9] In a cohort study conducted at the North Sea of Norway, Irgens et al (2007) also reported a rate of divers' DCS experience as high as 70.0% (161) of 230 divers.[10] Similarly, hookah and helmet divers showed a high incidence of DCS in the Kyushu area in Japan,[11] and hookah divers in the Pescadores (Penghu) islands in Taiwan and China had reportedly experienced DCS 3.1 times on average.[12] Westin et al (2005) evaluated the risk of DCS in sea cucumber fishery divers in the Galapagos islands of Ecuador, where the median cumulative probability of DCS reached 9.4% (4.3%-25.4%) within only 7 days of diving practice.[13]

There are legislative measures, such as periodic health examinations, undertaken to protect workers in a high-pressure environment. Nevertheless, unlike industrial divers, fishery divers are often beyond the scope of the law as there are no registries of fishery divers established in Korea. We are reporting this study because the characteristics of diving practice and the incidence of diving-related diseases in Korean fishery divers have not been reported elsewhere than in Korea even though there are a sizable number of fishery divers in Korea and the reported risk of DCS is considerably high.

2 | METHODS

2.1 | Study participants

This study was conducted from June to September 2008. A total of 215 boat owners with permission of fishery diving were registered in the database of the Ministry of Oceans and Fisheries. We sent out questionnaires to them and requested that the employed divers could participate in the research. They kindly replied to us by mail, and a total of 196 divers (114 from the southern coast, 60 from the eastern coast, and 22 from the western coast) participated in this study.

2.2 | Questionnaires

The questionnaire was comprised of demographical characteristics, diving-related characteristics, and experiences with DCS. Demographical characteristics contained participants' age, gender, and education. The diving-related characteristics included questions asking diving career length, how they learned the different diving techniques, commonly used diving apparatus (SSD or SCUBA), if they work with assistance in pairs, if they follow the decompression table underwater, if they ascended rapidly and why they did it, and the intensity of their work (average months per year, days per month, dives per day, hours per dive, usual working depth, and surface interval time between dives). The intensity of work was surveyed separately between heavy-, medium-, and light-loading seasons. In the experiences with DCS section of the questionnaire, we asked if they had used recompression chamber, if they had experienced DCS-related symptoms, and what their first-line therapies were to treat the symptoms.

2.3 | Symptoms of DCS types I and II

We classified the DCS with its characteristics based on the data obtained from questionnaires. Participants who had experienced pain in the upper or lower limbs, itching skin, or rash were considered to have experienced DCS type I. On the other hand, generalized weakness, paresthesia and numbness, respiratory difficulty and chest pain, dizziness and vomiting, auditory disturbance, and urinary disturbance were classified as the symptoms of the DCS type II.

2.4 | Data analysis

Demographical and diving-related characteristics were statistically described, and the difference in the incidence of DCS symptoms based on these characteristics was analyzed using chi-square test. Mean differences in diving career length, months per year, days per month, dives per day, bottom time

per dive, working depth, and surface interval time according to the DCS symptoms were analyzed using Student's t test. The differences in the distribution of the incidence of DCS symptoms were stratified by the frequency of dives per day, average working depth, and the average bottom time and were analyzed using chi-square test. Logistic regression analysis was used to evaluate the size of the influence of the characteristics on the incidence of DCS symptoms. A *P*-value below 0.05 was considered statistically significant.

3 | RESULTS

3.1 | General and diving-related characteristics

Of 196 divers, 96 (49.0%) were aged 40-49 years, 62 (31.6%) were aged 50 years or older, and the mean was 46.2 ± 8.4 years. Approximately 87.8% of the divers were male, and 56.1% of them graduated high school or attained a higher educational level (Table 1).

Their average length of career in fishery diving was 18.1 ± 8.5 years, and as many as 79.6% of the divers were hookah divers. About 68.4% of the divers responded that they learned different diving techniques from assisting senior divers, but from legitimate diving instructors.

According to the responses, they were working for 10.8 ± 1.9 months per year. During the heavy-loading season, they were working for 18.7 ± 5.4 days per month, which was significantly more ($P < 0.05$) than 11.4 ± 5.7 days per month during light-loading season and 14.8 ± 5.1 days per month during medium-loading season. Similarly, the average number of dives per day was higher ($P < 0.05$) during the heavy-loading season, where the responses revealed 5.4 ± 1.6 dives, 3.9 ± 1.3 dives, and 2.9 ± 1.1 dives per day during heavy-, medium-, and light-loading seasons, respectively.

An average bottom time was 74.7 ± 23.3 minutes, the average depth was 23.6 ± 6.8 m, and the average surface interval time was 20.7 ± 12.5 minutes. A lot of the divers were working solo without a buddy (86.7%), and only a few performed underwater decompression according to the decompression table (12.2%). About 93.9% of the divers experienced a rapid ascent, which was mostly (82.7%) caused by an abrupt stop of air flow (Table 2).

TABLE 1 General characteristics of fishery divers

Characteristics	Fishery divers (n = 196)	
	N (%)	Mean ± SD
Age (years)		46.2 ± 8.4
≤39	38 (19.4)	
40-49	96 (49.0)	
≥50	62 (31.6)	
Gender		
Male	172 (87.8)	
Female	24 (12.2)	
Education		
Elementary school and lower	27 (13.8)	
Middle school	59 (30.1)	
High school and higher	110 (56.1)	

SD, standard deviation.

3.2 | The incidence of DCS with general and diving-related characteristics

The incidence of DCS symptoms among the total participants was 84.7%. As for the symptoms of DCS type I, pain in the upper or lower limbs accounted for 73.8% and 63.8%, respectively, and skin itching and rash accounted for 67.9% and 49.0%, respectively. More than 40% of the divers had experienced the symptoms of DCS type II, such as paresthesia and numbness, respiratory difficulty and chest pain, and generalized weakness (Table 3).

The incidence of DCS symptoms was higher in female divers than in male divers ($P < 0.05$) and was higher in divers with higher educational status ($P < 0.05$). Moreover, the incidence increased as working days per month and dives per day increased ($P < 0.05$). An increased average working depth and a short surface interval time tended to reflect an elevated incidence in the DCS symptoms ($P < 0.01$). Those who did not obey the decompression rules or those who had experienced a rapid ascent also showed a higher incidence of DCS symptoms ($P < 0.05$) (Table 4).

3.3 | Incidence of DCS with the depth, bottom time, and frequency of dives

The incidence of DCS symptoms was stratified by the following diving profiles: average working depth, frequency of dives per day, and average bottom time. Those who were diving seven times or more per day had all experienced the DCS symptoms regardless of the working depth or the bottom time. For those who were working at 30 m depth or deeper and five times or more per day, 94.4% of the divers responded to have experienced the DCS symptoms. Results showed that the average depth and frequency of dives per day influenced the incidence of the DCS symptoms more than the bottom time (Table 5).

3.4 | Logistic regression analysis of decompression sickness

The results of logistic regression analysis showed that the more the diving days per month and the more frequent the dives per day, the riskier the divers were at experiencing total

TABLE 2 Distribution of fishery divers by diving-related characteristics

Characteristics	Fishery divers (n = 196)	
	N (%)	Mean ±SD
Duration of diving (years)		18.1 ± 8.5
≤9	35 (17.9)	
10-19	71 (36.2)	
≥20	88 (44.9)	
No response	2 (1.0)	
Diving gear		
SSD	163 (83.2)	
SCUBA	12 (6.1)	
SSD and SCUBA	21 (10.7)	
Diving education		
Diving instructor	25 (12.7)	
Senior coworker	134 (68.4)	
Military	35 (17.9)	
Others	2 (1.0)	
Diving months per year (n = 194)		10.8 ± 1.9
≤7	13 (6.7)	
8-9	16 (8.3)	
10-11	53 (27.3)	
12	112 (57.7)	
Diving days per month		
Heavy-loading season (n = 162)		18.7 ± 5.4
≤9	10 (6.2)	
10-19	47 (29.0)	
≥20	105 (64.8)	
Medium-loading season (n = 173)		14.8 ± 5.1
≤9	32 (18.5)	
10-19	83 (48.0)	
≥20	58 (33.5)	
Light-loading season (n = 154)		11.4 ± 5.7
≤9	53 (34.4)	
10-19	82 (53.3)	
≥20	19 (12.3)	
Frequency of dive per day		
Heavy-loading season (n = 196)		5.4 ± 1.6
1-4	54 (27.6)	
5-6	110 (56.1)	
7-10	32 (16.3)	
Medium-loading season (n = 193)		3.9 ± 1.3
1-4	146 (75.7)	
5-6	40 (20.7)	
7-10	7 (3.6)	
Light-loading season (n = 148)		2.9 ± 1.1
1-4	138 (93.2)	
5-6	10 (6.8)	
7-10	0 (0.0)	
Routine depth (m) (n = 196)		23.6 ± 6.8
≤10	13 (6.6)	
11-29	107 (54.6)	
≥30	76 (38.8)	
Average bottom time (min) (n = 196)		74.7 ± 23.3
≤49	45 (23.0)	
50-69	34 (17.3)	
70-85	33 (16.8)	
≥86	84 (42.9)	
Surface interval time (min) (n = 196)		20.7 ± 12.5
≤10	46 (23.5)	
11-29	107 (54.6)	
≥30	43 (21.9)	
Buddy system		
Solo	170 (86.7)	
Buddy	8 (4.1)	
Alternative	18 (9.2)	
Decompression (in water) (n = 196)		
Yes with strict rule	24 (12.2)	
Yes without rule	76 (38.8)	
Yes with intermittent strict rule	89 (45.4)	
No	7 (3.6)	
Rapid ascent (n = 196)		
Yes	184 (93.9)	
No	12 (6.1)	
Causes of rapid ascent		
Abrupt stop of air flow	148 (82.7)	
Inexperienced control of BCD	18 (10.0)	
Sudden change in underwater environment	6 (3.4)	
Dangerous underwater animal	2 (1.1)	
Others	5 (2.8)	

BCD: buoyancy compensating device, SCUBA: self-contained underwater breathing apparatus, SD: standard deviation, SSD: surface-supplied divers.

DCS-related symptoms (OR = 1.142, 95% CI = 1.023-1.274; and OR = 1.693, 95% CI = 1.045-2.742, respectively). Similarly, the results demonstrated that the divers were at higher risk of experiencing DCS type I symptoms with more diving days per month (OR = 1.209, 95% CI = 1.044-1.399) and with more frequent dives per day (OR = 1.679, 95% CI = 1.028-2.744). It also showed that the frequency of dives per day (OR = 1.760, 95% CI = 1.208-2.565), average bottom time (OR = 0.969, 95% CI = 0.950-0.988), and the rapid ascent (OR = 4.491, 95% CI = 1.118-18.034) were

TABLE 3 Distribution of fishery divers by decompression sickness and its symptoms within the recent year

DCS and its symptoms	Fishery divers (n = 196)
DCS I or DCS II experience	
Yes	166 (84.7)
No	30 (15.3)
DCS I symptoms	
Skin itching	133 (67.9)
Skin rash	96 (49.0)
Musculoskeletal pain (upper limb)	144 (73.5)
Musculoskeletal pain (lower limb)	125 (63.8)
DCS II symptoms	
Generalized weakness	84 (42.9)
Paresthesia and numbness	94 (48.0)
Respiratory difficulty and chest pain	88 (44.9)
Dizziness and vomiting	65 (33.2)
Auditory disturbance	71 (36.2)
Urinary disturbance	40 (20.4)

Values are represented as N (%).
DCS: decompression sickness, DCS I: decompression sickness type I, DCS II: decompression sickness type II.

statistically significant contributing characteristics to experiencing DCS type II symptoms (Table 6).

4 | DISCUSSION

4.1 | Incidence of DCS

In Korea, current estimates of fishery divers ranged from 1180 to 1900. However, the estimated number of professional divers is 3000, including industrial divers working in shipyards and underwater construction sites, and a considerable number of fishery divers work only part-time during the heavy-loading season rather than full-time throughout the whole season.

In this study, 84.7% of the divers had experienced the DCS symptoms within a year. This number is greater than 69.5%[5] and 61.1%[2] in the previous studies. We believe that this increase in number is due to the change in diving profiles as the divers nowadays are working deeper and longer than before because of the increasing demands in marine products yet decreasing marine resources. As most of the divers are implementing hookah-diving method to work with less restriction to working time, we suspect that the DCS was primarily caused by repetitive dives five times a day or more and ignoring the underwater decompression procedures. Furthermore, the high prevalence of DCS was caused by the lack of diving-related healthcare facilities in Korea that resulted in a low accessibility and a delayed, longer transfer time, increasing the rate of DCS sequelae even after treatment.

4.2 | Incidence of DCS with the age

Previous studies stated that the incidence of DCS increased with increasing age, and a study showed that the incidence even doubled in divers aged 28 years than those aged 18 years.[6,14] Moreover, McAniff (1989) reported that divers aged over 50 years had higher DCS mortality and morbidity rates.[15] In this study, however, there were no significant differences in the incidence of DCS symptoms in various age groups. This is due to the fact that younger divers dive deeper, longer, and more frequently than the older ones.

4.3 | Incidence of DCS with the gender

Female divers showed a higher incidence of DCS symptoms (100%) than male divers. This finding is consistent with the results of Edmonds et al (2002)'s study, which showed that the incidence of DCS symptoms in female divers was three times higher than those of male divers. However, as a recent study[16] claimed that the effect of gender on the DCS remains unclear and only 24 female divers were included in this study, a further study with a larger number of female divers is necessary to draw a clearer conclusion on this matter.

4.4 | Incidence of DCS with the diving patterns and rapid ascent

Hookah diving was the most commonly used diving technique (90.3%) among the divers in this study. This method has less restriction to the duration of air supply and, therefore, allows divers to stay underwater longer than those with other diving methods such as SCUBA diving and breath-hold diving. If hookah divers perform repetitive dives with rapid ascents to boost the productivity, they are highly likely to experience the DCS.

In Korea, most of the registered boats with diving apparatus are small boats weighing 5-10 tons and are equipped with an air compressor to supply compressed air to divers. During SSD with hookah, a discontinuation or an entanglement of the air hose causes an immediate cessation of air flow and divers to ascend rapidly to the surface, which may lead to the development of pulmonary overinflation syndrome. In this study, 93.9% of the divers experienced a rapid ascent, and the abrupt stop of air flow was the most common cause (82.7%). Approximately 71.7% of those who had experienced a rapid ascent also had experienced symptoms of DCS type II. As rapid ascents may result in fatal consequences in fishery divers, it is necessary to take appropriate measures, such as replacing outdated air compressors and restricting other ship from sailing in the diving area.

TABLE 4 Incidence of DCS in fishery divers by general and diving-related characteristics

Characteristics	N	DCS I	DCS II	Total
Age (years)				
≤39	38	31 (81.6)	25 (65.8)	32 (84.2)
40-49	96	85 (88.5)	70 (72.9)	86 (89.6)
≥50	62	47 (75.8)	42 (67.7)	48 (77.4)
Gender		*	†	*
Male	172	139 (80.8)	114 (66.3)	142 (82.6)
Female	24	24 (100.0)	23 (95.8)	24 (100.0)
Education		*		*
Elementary school and lower	27	19 (70.4)	17 (63.0)	20 (74.1)
Middle school	59	46 (78.0)	40 (67.8)	46 (78.0)
High school and higher	110	98 (89.1)	80 (72.7)	100 (90.9)
Duration of diving (years)				
≤9	35	28 (80.0)	26 (74.3)	29 (82.9)
10-19	71	63 (88.7)	50 (70.4)	64 (90.1)
≥20	88	70 (79.5)	59 (67.0)	71 (80.7)
Diving education				
Diving instructor	25	23 (92.0)	16 (64.0)	24 (96.0)
Senior coworker	134	110 (82.1)	97 (72.4)	111 (82.8)
Military	35	28 (80.1)	23 (65.7)	29 (82.9)
Diving gear				
SSD	163	134 (81.4)	112 (67.9)	136 (82.7)
SCUBA	12	9 (75.0)	8 (66.7)	10 (83.3)
SSD and SCUBA	21	20 (95.2)	17 (81.0)	20 (95.2)
Diving months per year				
≤7	13	12 (92.3)	11 (84.6)	12 (92.3)
8-9	16	14 (87.5)	11 (68.8)	14 (87.5)
10-11	53	47 (88.7)	38 (71.7)	48 (90.6)
12	112	88 (78.6)	75 (67.0)	90 (80.4)
Diving days of month				
Heavy-loading season		†	*	†
≤9	10	3 (30.0)	3 (30.0)	3 (30.0)
10-19	47	36 (76.6)	32 (68.1)	37 (78.7)
≥20	105	95 (90.5)	76 (72.4)	96 (91.4)
Medium-loading season		†	†	†
≤9	32	17 (53.1)	17 (53.1)	18 (56.3)
10-19	83	71 (85.5)	55 (66.3)	73 (88.0)
≥20	58	55 (94.8)	48 (82.8)	55 (94.8)
Light-loading season		†		*
≤9	53	36 (67.9)	34 (64.2)	38 (71.7)
10-19	82	72 (87.8)	56 (68.3)	73 (89.0)
≥20	19	18 (94.7)	16 (84.2)	18 (94.7)
Frequency of dive per day				
Heavy-loading season		†	†	*
1-4	54	41 (75.9)	32 (59.3)	43 (79.6)

(Continues)

TABLE 4 (Continued)

Characteristics	N	DCS I	DCS II	Total
5-6	110	90 (81.8)	76 (69.1)	91 (82.7)
7-10	32	32 (100.0)	29 (90.6)	32 (100.0)
Medium-loading season		*	†	*
1-4	146	116 (79.5)	94 (64.4)	119 (81.5)
5-6	40	38 (95.0)	34 (85.0)	38 (95.0)
7-10	7	7 (100.0)	7 (100.0)	7 (100.0)
Light-loading season				
1-4	138	122 (88.4)	99 (71.7)	124 (89.9)
5-6	10	10 (100.0)	9 (90.0)	10 (100.0)
7-10	0	0 (0.0)	0 (0.0)	0 (0.0)
Average bottom time (min)		*	*	*
≤49	45	42 (93.3)	37 (82.2)	43 (95.6)
50-69	34	31 (91.2)	30 (88.2)	31 (91.2)
70-85	33	30 (90.9)	26 (78.8)	30 (90.9)
86≤	84	60 (71.4)	44 (52.4)	62 (73.8)
Average depth (m)		*		
≤10	13	9 (69.2)	9 (69.2)	10 (76.9)
11-29	107	85 (79.4)	73 (68.2)	87 (81.3)
30≤	76	69 (90.8)	55 (72.4)	69 (90.8)
Surface interval time (min)				†
≤10	46	43 (93.5)	34 (73.9)	44 (95.7)
11-29	107	84 (78.5)	72 (67.3)	86 (80.4)
30≤	43	36 (83.7)	31 (72.1)	36 (83.7)
Buddy system				
Solo	170	142 (83.5)	116 (68.2)	145 (85.3)
Buddy	8	5 (62.5)	5 (62.5)	5 (62.5)
Alternative	18	16 (88.9)	16 (88.9)	16 (88.9)
Decompression (in water)		*		*
Yes with strict rule	24	20 (83.3)	17 (70.8)	20 (83.3)
Yes without rule	76	70 (92.1)	57 (75.0)	71 (93.4)
Yes with intermittent strict rule	89	67 (75.3)	57 (64.0)	68 (76.4)
No	7	6 (85.7)	6 (85.7)	7 (100.0)
Rapid ascent			*	
Yes	184	155 (84.2)	132 (71.7)	158 (85.9)
No	12	8 (66.7)	5 (41.7)	8 (66.7)

Values are represented as N (%, incidence).
DCS I: decompression sickness type I, DCS II: decompression sickness type II, SCUBA: self-contained underwater breathing apparatus, SSD: surface-supplied divers.
*$P < 0.05$,
†$P < 0.01$ incidence comparison of DCS I, DCS II, and the total DCS between divisions of each characteristics by chi-square.

4.5 | Incidence of DCS with the source of diving technique

Most of the divers included in this study learned the different diving techniques from their senior divers (68.4%), and only a few had had proper training from legitimate institutions such as from the military (17.9%) and diving instructors (12.7%). Therefore, it is necessary for fishery divers to learn the different diving techniques from an appropriate institution to lower the incidence of DCS.

TABLE 5 Incidence of decompression sickness of fishery divers by diving profiles

Average depth (m)	Frequency of dive per day			Total
	1-4	5-6	7-10	
≤10	2/4 (50.0)	4/5 (80.0)	4/4 (100.0)	10/13 (76.9)
11-29	17/21 (81.0)	53/69 (76.8)	17/17 (100.0)	87/107 (81.3)
≥30	24/29 (82.8)	34/36 (94.4)	11/11 (100.0)	69/76 (90.8)
Total*	43/54 (79.6)	91/110 (82.7)	32/32 (100.0)	166/196 (84.7)

Average depth (m)	Average bottom time (min)				Total
	≤49	50-69	70-85	≥86	
≤10	5/6 (83.3)	1/1 (100.0)	3/4 (75.0)	1/2 (50.0)	10/13 (76.9)
11-29**	22/23 (95.7)	20/22 (90.9)	10/11 (90.9)	35/51 (68.6)	87/107 (81.3)
≥30	16/16 (100.0)	10/11 (90.9)	17/18 (94.4)	26/31 (83.9)	69/76 (90.8)
Total**	43/45 (95.6)	31/34 (91.2)	30/33 (90.9)	62/84 (73.8)	166/196 (84.7)

Frequency of dive per day	Average bottom time (min)				Total
	≤49	50-69	70-85	≥86	
1-4	12/14 (85.7)	5/6 (83.3)	10/11 (90.9)	16/23 (69.6)	43/54 (79.6)
5-6†	15/15 (100.0)	18/20 (90.0)	17/19 (89.5)	41/56 (73.2)	91/110 (82.7)
7-10	16/16 (100.0)	8/8 (100.0)	3/3 (100.0)	5/5 (100.0)	32/32 (100.0)
Total†	43/45 (95.6)	31/34 (91.2)	30/33 (90.9)	62/84 (73.8)	166/196 (84.7)

The values are expressed as the number of divers who have experienced decompression sickness/the number of total divers in each cell (incidence).
Frequency of dive per day means frequency of dive per day in the heavy-loading season.
*$P < 0.05$ incidence comparison of the total average depth among diving-frequency groups by chi-square.
**$P < 0.01$ incidence comparison of 11-29 m and the total average depth among average-bottom-time groups by chi-square.
†$P < 0.05$ incidence comparison of 5-6 dives per day and total diving frequency among average-bottom-time groups by chi-square.

4.6 | Incidence of DCS with the diving patterns: depth and frequency of dives

Fishery divers, unlike farmers whose workspace is the land, earn more as they dive farther, deeper, and longer in a broader area of the sea. Because of this, they tend to dive competitively deeper, longer, and more frequently with merely a short surface time. Korean fishery divers are working under circumstances completely disregarding decompression schedules as a result of competitive diving.

Although working in a deeper environment requiring stricter decompression, repetitive diving, and multiple ascents in a single dive are all risk factors of DCS, repetitive diving was more risky.

A lot of participants in this study had been diving frequently. Even in the analysis after stratifying with working depth and the bottom time, nearly all of those who dive 7 to 10 times responded to have experienced the DCS symptoms. Therefore, the frequency of dives per day seems to play a more important role in causing DCS than the other diving habits.

Korean fishery divers' diving profile is far from the non-decompression limits. During the heaving-loading season, they are working for more than 20 days per month (64.8%), 74.7 minutes per dive, at 23.6 m depth on average, with less than 10 minutes of surface time (23.5%), and a predominant number of them (93.4%) are diving below 11 m. With these diving patterns, the DCS will not cease to occur.

5 | LIMITATIONS

We could not evaluate the response rate because the actual size of the entire subjects remains unknown. Divers with severe DCS sequelae might be hospitalized or might not have survived, and young healthy divers might not have responded to the questionnaire. Therefore, there might be selection bias in this study.

There are several risk factors disregarded in this study. For example, cigarette smoking, alcohol consumption, and obesity are thought to be related with the incidence of DCS. However, we did not include them in the questionnaire because we were concerned that requesting private information might decrease the response rate drastically from reluctant participants. Low temperature of the water is another important risk factor. A further study should investigate related factors more extensively and subdivide the coastal areas to analyze the relationship with the incidence of DCS.[6,7]

TABLE 6 Logistic regression analysis of decompression sickness among 196 fishery divers

Variable	Coefficient (β)	SE of coefficient	Exp (β)	95% CI	*P*
TDCS					
Intercept	−3.205	2.039	0.041		0.116
Education					
0 = Elementary school and lower					
1 = Middle school	−0.288	0.663	0.749	0.204-2.751	0.664
2 = High school and higher	0.146	0.783	1.157	0.249-5.365	0.852
Diving days per month	0.132	0.056	1.142	1.023-1.274	0.018
Frequency of dive per day	0.527	0.246	1.693	1.045-2.742	0.032
Average bottom time	−0.021	0.012	0.979	0.956-1.002	0.078
Average depth	0.077	0.046	1.080	0.987-1.181	0.094
DCS I					
Intercept	−6.767	2.658	0.001		0.011
Education					
0 = Elementary school and lower					
1 = Middle school	0.085	0.675	1.088	0.290-4.084	0.900
2 = High school and higher	0.739	0.825	2.094	0.416-10.542	0.370
Diving education					
0 = Diving instructor					
1 = Senior coworker	0.713	0.998	2.039	0.288-14.429	0.475
2 = Military	−1.313	1.070	0.269	0.033-2.189	0.220
Diving days per month	0.190	0.075	1.209	1.044-1.399	0.011
Frequency of dive per day	0.518	0.250	1.679	1.028-2.744	0.038
Average bottom time	−0.007	0.013	0.993	0.968-1.018	0.575
Average depth	0.071	0.044	1.073	0.984-1.170	0.110
Decompression (in water)					
0 = Yes with strict rule					
1 = Yes without rule	1.828	0.988	6.220	0.897-43.123	0.064
2 = Yes with intermittent strict rule	0.819	0.942	2.267	0.358-14.365	0.385
3 = No	−0.081	1.498	0.923	0.049-17.385	0.957
DCS II					
Intercept	−6.767	1.590	0.124		0.189
Diving days per month	0.040	0.036	1.040	0.969-1.117	0.275
Frequency of dive per day	0.565	0.192	1.760	1.208-2.565	0.003
Average bottom time	−0.032	0.010	0.969	0.950-0.988	0.001
Average depth	0.014	0.030	1.014	0.956-1.075	0.645
Rapid ascent					
0 = No					
1 = Yes	1.502	0.709	4.491	1.114-18.034	0.034

TDCS: total decompression sickness, DCS I: decompression sickness type I, DCS II: decompression sickness type II.

To include as many divers as possible, we used questionnaires, which may be somewhat unreliable. A lot of divers reported the symptoms of DCS more than once a year, but we only accounted the number of divers with the experience to calculate the incidence. As the subjects had been diving frequently and repeatedly for years, it was also extremely difficult to ask about specific DCS episodes via questionnaires as well as for them to answer to such questions. It would also have been best to validate the symptoms by reviewing hospital records, but

it was not possible to design the study in such a way due to practical difficulties. Alternatively, we assumed that they were aware of the symptoms of 'bends' with repeated exposures and composed the questions of the symptoms listed in the textbook.[6] As for divers with various work areas, we had to request the description of the main area only.

6 | CONCLUSIONS

Korean fishery divers have high incidence of DCS. They are susceptible to DCS as they perform repetitive dives to earn a living. As we are estimating that over 3000 divers neglected the decompression schedules, the incidence of DCS and other diving-related diseases does not seem to be declining in the near future. A predominant number of divers are neglecting the DCS symptoms such shoulder pain and skin itching and fall into a vicious cycle of relieving the symptoms by underwater recompressions. Instead of hyperbaric oxygen therapy in a recompression chamber, they are customarily treating themselves with hot tub, self-medication, or alcohol drinking. As the diving depth, frequency, and bottom time are directly proportional to the divers' income, it is not easy to strictly follow the time-consuming decompression schedules. Nevertheless, safe diving with proper decompression and modernized diving equipment is crucial for preventing the DCS as well as the secondary prevention by early recovery.

In Korea, there are only a few active recompression facilities that are practically inaccessible to the divers, and increasing the number of such facilities may promote the secondary prevention of the DCS. In addition, although the diving-related legislation contains regulations regarding the health examinations for workers working in a high-pressure environment and management/operation of diving equipment, fishery divers are often beyond the scope of the law. To establish a disease surveillance system, it is necessary to build registries of fishery divers so that they benefit from the legislative measures, such as the mandatory periodic health examination.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

DISCLOSURE

Approval of the research protocol: N/A. *Informed consent:* N/A. *Registry and the Registration no. of the study/trial:* N/A. *Animal studies:* N/A.

AUTHORS' CONTRIBUTIONS

SGC and YSB wrote the draft of the manuscript. SGC, MJJ, and JS planned and designed the study. SGC made contributions to recruitment of participants and acquisition of data. SGC and YSB contributed to reviewing precious research. SGC, YSB, MJJ, and JS analyzed and interpreted data. MJJ and JS critically reviewed the manuscript. All authors read and approved the final manuscript.

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