의학석사 학위논문

Rehabilitation Outcome in People with Spinal Cord Injuries Resulting from Diving in South Korea

한국 내 다이빙으로 인한 척수 손상 환자에서 재활 결과

2021년 2월

서울대학교 대학원

임상의과학과

윤 재 현

Rehabilitation Outcome in People with Spinal Cord Injuries Resulting from Diving in South Korea

지도교수 방 문 석

이 논문을 의학석사 학위논문으로 제출함

2020년 10월

서울대학교 대학원

임상의과학과

윤 재 현

윤재현의 의학석사 학위논문을 인준함

2021년 1월

위 원 장 신형익 (인)

부 위 원 장 방문석 (인)

위 원 (인)

ABSTRACT

Rehabilitation Outcome in People with Spinal Cord Injuries Resulting from Diving in South Korea

Jae-Hyun Yun

Department of Clinical Medical Sciences,

Seoul National University College of Medicine

Background: As economy of South Korea grows, interest in leisure activity and sports has been increasing, and diving is no longer a rare cause of traumatic spinal cord injury (SCI). To prevent SCI due to diving accident, general information and risk factors are necessary, but there has been a paucity of studies about SCI due to diving accident in South Korea.

Objectives: The purpose of this study is to describe the demographics and neurological outcomes in people with diving injuries of the cervical spine. We also investigated circumstances at the time of diving injury in order to identify the risk factors, and general rehabilitation outcomes after SCI.

Methods: People with SCI due to diving accident who went to Seoul National University Hospital from 2000 to 2019 and National Traffic Injury Rehabilitation Hospital from 2014 to 2019 were investigated. The electronic medical records were reviewed for medical and neurologic information. Then, telephone interviews were performed with questionnaire regarding specific circumstances at the time of injury and social status.

Results: A total of 33 people with SCI due to diving accident were analysed and 27 persons responded to telephone interviews. 32 (97%) participants were male and 27 (81.8%) were younger than 40 years at the time of injury. American Spinal Injury Association A grade was the most common with 16 (48.5%) participants, and C4 was the most common neurologic level of the injury (n=13, 39.4%). SCI due to diving accident most commonly occurred in swimming pool in holiday lodge (n=12, 36.4%). 5 out of 13 married couples with motor complete deficit were divorced or separated after injury. 8 out of 33 persons started their job or study again after injury, with mean (SD) return time 33 (24.4) months.

Conclusions: SCI resulting from diving accident causes not only functional severe impairment but also changes of marital and employment status. Our study can be used as basic source of education and publicity needed to prevent further SCI due to diving accident.

Keywords: Spinal cord injuries, Diving, Risk factors, Tetraplegia

Student Number: 2019-23243

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INRODUCTION

Spinal cord injury (SCI) is regarded as second common serious traumatic event following traumatic brain injury, and causes devastating consequences, leaving various problems throughout victim's life, including tetraplegia or paraplegia[1]. Especially, people with SCI due to diving accidents usually have more severe disabilities than other etiology of SCI, such as motor vehicle accidents or falls, because most of them are injured in higher levels of cervical vertebrae, resulting in tetraplegia than paraplegia [2-4].

Several studies have been reported regarding epidemiology of traumatic SCI in many countries, and the incidence of SCI due to diving was various depending on regions and countries. The proportion of diving accidents in traumatic SCI was the highest in Australia (9.4%), Brazil (9.3%), and Finland (9.2%), followed by United States (8.5%), Canada (2.4%), and Japan (1.3%)[5-9]. In 2016, systematic review regarding the epidemiology of sport-related SCI reported that diving is a common cause of sport-related SCI, ranging from 7.7% in Germany to 64.9% in China[10]. The difference of natural environment and the rate of people who enjoy diving was thought to be the reason why the rate of incidence of diving accidents varied from country to country[11]. On the other hands, several studies reported the increase of SCI related with leisure activity and sports has been emerging issue in countries going from developing to developed country[12, 13].

A few studies were conducted on the epidemiology of SCI in South Korea although there are no national statistics regarding the cause of spinal cord injury in South Korea. In 1999, Park et al. reported that sport-related SCI ranked 4th common cause of traumatic SCI with 4.1%, and diving accident was the most common (40.9%) etiology of sport-related SCI[14]. In 2016, Lee et al. reported that diving induced SCI accounted for 2.6% of traumatic SCI in South Korea, and it ranked as fourth common causes of traumatic SCI[15]. Therefore, diving accident is not a rare cause of the traumatic SCI in Korea, and prevention of diving accidents should be emphasized.

Since SCI due to diving accident commonly occurs in young age and makes victim more disabled than other etiology, they would live with life-long severe disability for decades[2, 3, 16]. Thus, it is more catastrophic for victims and caregivers, and their socioeconomic costs are great. According to 2010 report of National Spinal Cord Injury Statistical Center, the life expectancy of people with cervical SCI occurred at the age of 20 is 41 years for neurologic level of injury between C5-8, and 37 years for between C1-4[17]. A study conducted in France regarding socioeconomic consequences of persons with SCI after diving injures reported that overall direct cost of treatment and hospitalization ranged from 14,000 to 364,000 dollars depending on their severity of injury[16]. In the United States, lifetime cost for 25 years old with a high cervical SCI with tetraplegia averaged 2.8million dollars, compared to 1.6million dollars for 50 years old[3]. If SCI caused by a diving accident can be prevented, not only the cost of healthcare but also the socio-economic burden could be reduced.

To date, there has been a paucity of studies about SCI due to diving accident in South Korea. As economy of South Korea grows, interest in leisure activity and sports has been increasing. Thus, the chances of SCI due to diving accident are anticipated to increase. In the present study, we reviewed our experience with people with diving injuries to describe their injuries and neurological outcome. We interviewed the people with SCI to investigate the circumstance at the time of diving injures in order to identify the risk factors of SCI due to diving accident. In addition, marital and employment status were also investigated to examine socio-professional outcome.

MATERIALS AND METHODS

Study location and the population

People with SCI due to diving accident who visited Seoul national university hospital (SNUH) from January 2000 to December 2019 and National traffic injury rehabilitation hospital (NTIRH) from October 2014 to December 2019 were investigated. SNUH is a tertiary hospital located in Seoul, which is the capital of South Korea and has a population of about 9.7million. NTIRH was established in 2015 by the Ministry of Land, Infrastructure and Transport and is an affiliate of SNUH, which is located in Yangpyeong, Gyeonggi-do.

Study design

A retrospective electronic medical records were conducted in people with SCI due to diving injury. Through medical records review, age, gender, date of injury, neurological status with American Spinal Injury Association (ASIA) impairment scale at date of admission and discharge, history of surgery, complications at hospitalization, and magnetic resonance imaging (MRI) findings were collected.

Then, telephone interviews were performed to people with SCI due to diving accidents regarding circumstances at the time of injury and social status before and after SCI. Informed consent was obtained from contacted persons after sufficient

explanation of the purpose and specific details of the study by telephone, and participants were surveyed on 27 questions through a pre-written structured questionnaire. Specific circumstances of injury including the time and location of injury, the site of diving, size and depth of the water, presence of depth indicator, presence of diving caution or prohibit sign, proficiency of diving and swimming, and frequency of swimming before injury, were investigated. We also surveyed the level of education, the job before injury, whether returning to the job, the amount of time to return to the job, the degree of change in working ability, and the marital status.

The study protocol was reviewed and approved by the Institutional Review Board of Seoul National University Hospital (IRB No. 1912-102-1089) and National Traffic Injury Rehabilitation Hospital (IRB No. NTRH-19008).

RESULTS

A total of 33 people with SCI due to diving accident were collected. 25 individuals visited NTIRH from 2014 to 2019, and 8 visited SNUH from 2000 to 2019. Diving accidents occurred to 3 people from 2000 to 2009, 3 from 2010 to 2014, and 27 since 2015. Of the 33 individuals, 27 responded to telephone interviews, 3 refused to answer, and 3 were not contacted.

Table 1 shows the characteristics of the individuals with SCI due to diving accidents. The mean (SD) age of the individuals with SCI was 31.4 (9.7) years and 81.8% (n=27) were younger than 40 years at the time of injury. 97% (n=32) participants were male. Most of participants (n=31) underwent surgery, and 2 took conservative treatment. 54.5% were in high school (n=4) or university or college (n=14) at the time of injury.

We collected 30 MRI imaging records of the total 33 participants, and fractures were found in 28 records. Burst fracture was the most common type of fracture with 23 participants, followed by dislocation or subluxation, with 9 participants. 5 participants were injured with both burst fracture and dislocation. Table 2 shows the distribution of fracture levels of burst fracture and dislocation or subluxation. C5 vertebra was the most common involved fracture level in burst fracture with 13 cases, followed by C4 and C6 vertebra, with 7 cases, respectively. Dislocation or subluxation occurred at C4/5 level with 5 cases and C5/6 with 4 cases.

Table 1. Characteristics of the individuals with spinal cord injury due to diving accidents

		n (%)
Gender	Male	32 (97.0)
	Female	1 (3.0)
Age in years at the time of injury	10~19	5 (15.2)
	20~29	11 (33.3)
	30~39	11 (33.3)
	40~49	5 (15.2)
	50~59	1 (3.0)
	>=60	0 (0.0)
Type of fracture	Burst	17 (51.5)
	Dislocation & Subluxation	4 (12.1)
	Burst & Teardrop	1 (3.0)
	Burst & Dislocation	5 (15.2)
	No fracture	2 (6.1)
	Etc.	1 (3.0)
	Unknown	3 (9.1)
Level of education at the time of injury	In high school	4 (12.1)
	In university or college	14 (42.4)
	University or college graduate	10 (30.3)
	Post-graduate or higher	2 (6.1)
	Unknown	3 (9.1)
Diving proficiency	Advanced	11 (33.3)
	Intermediate	7 (21.2)
	Beginner	9 (27.3)
	Unknown	6 (18.2)
Swimming proficiency	Advanced	13 (39.4)
	Intermediate	12 (36.4)
	Beginner	2 (6.1)
	Unknown	6 (18.2)
Safety education before injury	Yes	6 (18.2)
	No	21 (63.6)
	Unknown	6 (18.2)
Frequency of swimming	Daily	5 (15.2)
	1~2 times per week	2 (6.1)
	1~2 times per month	4 (12.1)
	several times in summer	16 (48.5)
	Unknown	6 (18.2)

Table 2. Distribution of fracture levels of burst fracture and dislocation or subluxation.

Burst fracture		Dislocation & Subluxation	
Fracture level	Number	Fracture level	Number
C2	0	C2/3	0
C3	1	C3/4	0
C4	7	C4/5	5
C5	13	C5/6	4
C6	7	C6/7	1
C7	4	C7/T1	0

Neurologic status of participants at the time of discharge is shown in Table 3, with ASIA grade and neurologic level of injury. The mean (SD) time of neurologic evaluation was 12.8 (9.8) months after injury. ASIA A was the most common with 16 people, followed by B (n=8), C (n=4), and D (n=5), and 72.7% (n=24) had motor complete injury. C4 was the most common neurologic level of injury (39.4%, n=13), followed by C5 (27.2%, n=9), and C6 (18.2%, n=6).

Table 4 shows the complications of people with SCI due to diving accident during hospitalization. Neurogenic bladder (n=33), neurogenic bowel (n=31), and neuropathic pain (n=20) were the most common complications, followed by respiratory difficulty (n=18), spasticity (n=18), and orthostatic hypotension (n=17).

Figure 1 shows the distribution of location where the SCI occurred due to diving and specific circumstances at the time of injury are analyzed in Table 5 and 6. Diving accidents occurred in swimming pool with 26 participants (78.8%), and in natural bodies of water with 7 participants (21.2%), and the place where diving accidents occurred most was swimming pool beside holiday lodge (36.4%, n=12), followed by swimming pools in sports center (15.2%, n=5), and valley (12.1%, n=4). More than half of accidents happened during the day (63.6%, n=21), rather than other time. Only for swimming pools, 30.3% (n=10) had SCI injury in small pools of length with less than 20 meters, and 24.2% (n=8) had accidents in pools larger than 25 meters. 54.5% (n=18) of diving accidents occurred at the water lower than 1.4 meter deep. 27.3% (n=9) of the accident sites had signs indicating the depth of the water and 21.2% (n=7) had diving warning signs. There were 18 sites where the accidents occurred at a depth of less than 1.4 meters, and only 2 of them had diving warning

signs. 6 of participants (18.2%) were drunken state at the time of injury. As shown in Figure 2, most of the accidents occurred in summer (70%, n=23), most commonly in August (n=10), followed by July (n=9).

Table 3. Neurologic status at the time of discharge

ASIA grade	n	Neurologic level of injury						
		C2	C3	C4	C5	C6	C7	C8
A	16	2	2	7	3	2	0	0
B	8	0	0	3	3	2	0	0
C	4	0	0	2	1	0	0	1
D	5	0	0	1	2	2	0	0
E	0	0	0	0	0	0	0	0
Total	33	2	2	13	9	6	0	1

ASIA American Spinal Injury Association

Table 4. Complications of people with spinal cord injury due to diving accident.

Complication	Number
Neurogenic bladder	33
Neurogenic bowel	31
Neuropathic pain	20
Respiratory difficulty	18
Spasticity	18
Orthostatic hypotension	17
Sore	7
Urinary tract infection	7
Autonomic dysreflexia	6
Heterotopic ossification	6
Dysphagia	5
Pneumonia	4
Cardiac arrest	1
Thrombosis (DVT or PE)	1

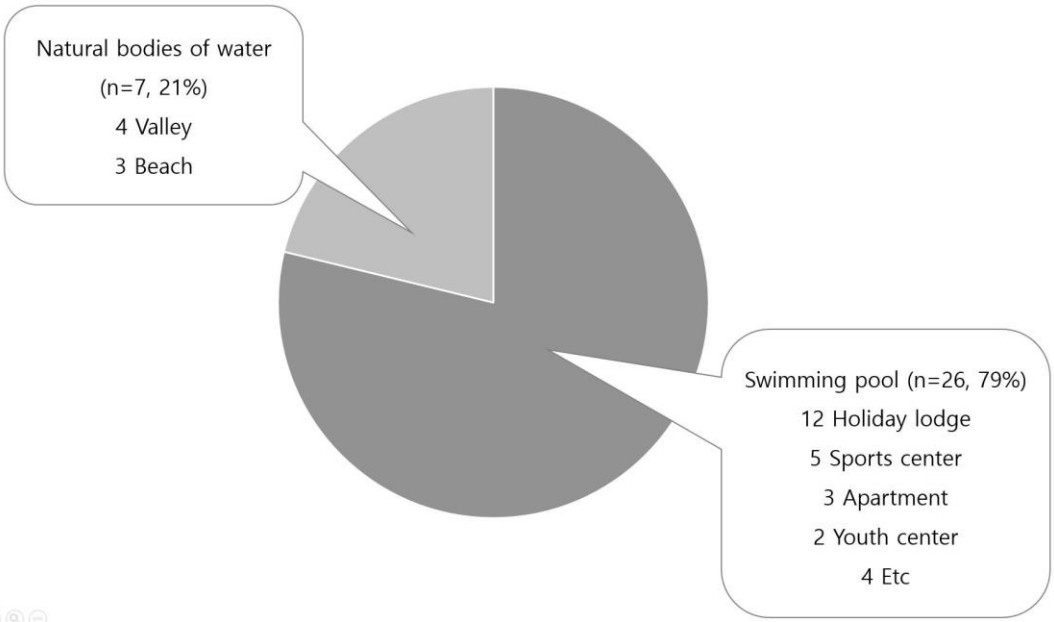

Figure 1. Distribution of the location where diving accident occurred

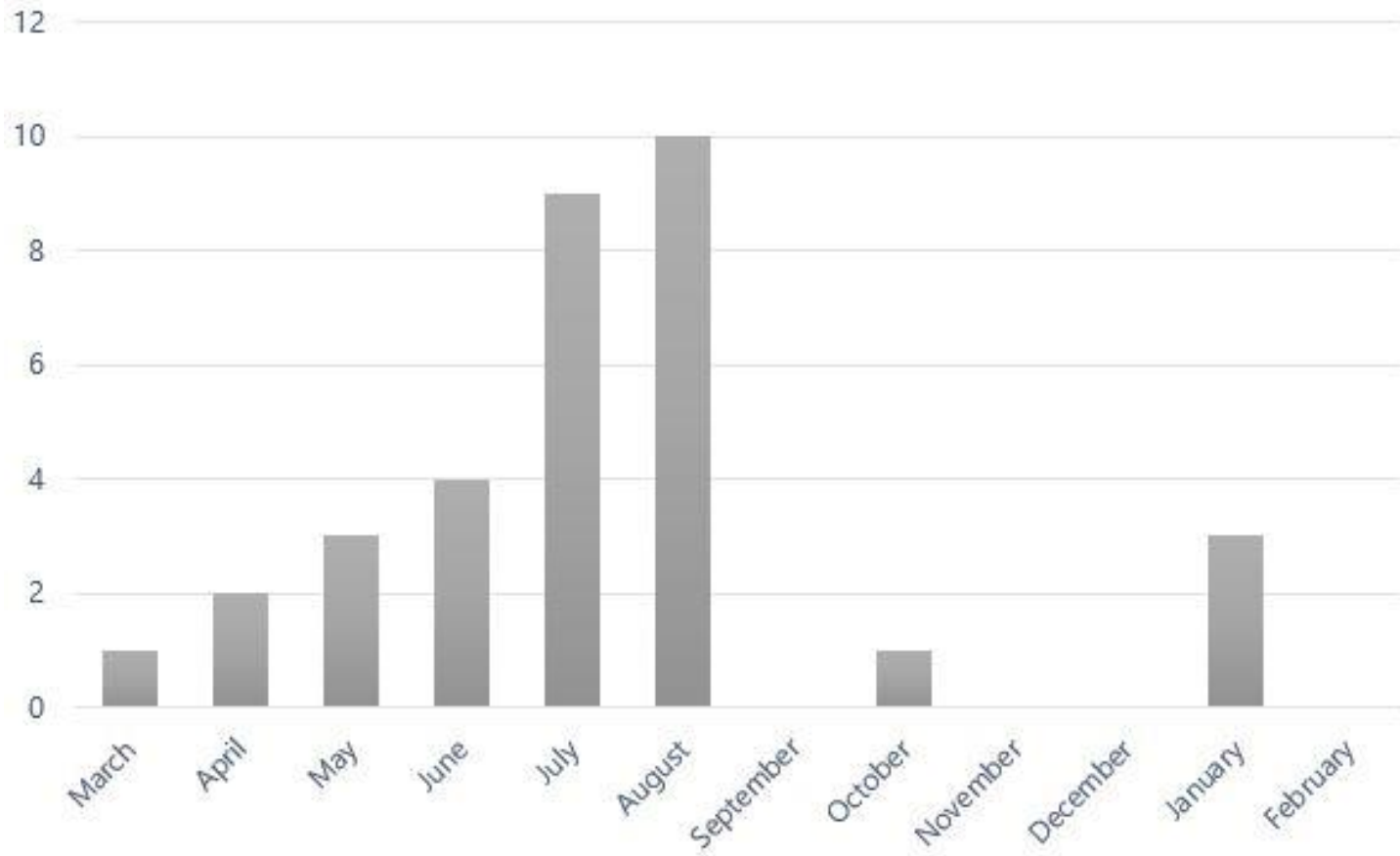

Figure 2. Distribution of people with spinal cord injury due to diving accident according to month

Table 5. Circumstances at the time of spinal cord injury

		number	%
Time of day	Morning & Evening	4	12.1
	Day	21	63.6
	Night & Dawn	4	12.1
	Unknown	4	12.1
Depth of the water	<1.4m	18	54.5
	>1.4m	13	39.4
	Unknown	2	6.1
Drunken state	Yes	6	18.2
	No	21	63.6
	Unknown	6	18.2
Presence of depth indicator	Yes	9	27.3
	No	18	54.5
	Unknown	6	18.2
Presence of diving caution sign	Yes	7	21.2
	No	20	60.6
	Unknown	6	18.2

Table 6. Distribution of circumstances at the time of SCI due to diving accident according to the injury site.

		Depth <1.4meters	Drunken state (+)	Depth indicator (+)	Diving caution sign (+)	Safety education (+)
Swimming pool	Holiday lodge (n=12)	11	4	1	1	3
	Sports center (n=5)	0	0	3	1	2
	Apartment (n=3)	0	1	3	3	0
	Youth center (n=2)	1	0	2	0	0
	Etc (n=4)	4	1	0	0	0
Natural bodies of water	Valley (n=4)	1	0	0	1	0
	Beach (n=3)	1	0	0	1	2
Total		18	6	9	7	7

More than half of participants responded their diving (54.5%, n=18) and swimming skills (75.8%, n=25) were above intermediate level, and more than one third said they were advanced level of diving (33.3%, n=11) and swimming (39.4%, n=13). 16 (48.5%) participants said they swam several times only in the summer, and only 6 (18.2%) reported that they (n=6) took safety education before diving accident.

Table 7 and 8 shows the change of marital and employment status after SCI due to diving accident. The mean time of telephone interview was 46.2 months (SD 28.2) after SCI. Of the 16 participants of ASIA A group, 9 were married before SCI due to diving, but four of them were divorced or separated after SCI. In ASIA B group, 4 were married before SCI, but one is separated after SCI. There were no change of marital status before and after SCI in contacted participants with ASIA C and D, except one person with ASIA D married after SCI.

As for employment status, in ASIA A group, 5 participants were students and 2 of them continued their studies, after 24 and 60 months after SCI, respectively. 11 participants had jobs at the time of SCI, and only one person had a job again, which is different from his previous job, 30 months after SCI. In ASIA B group, one participant was student and 7 had jobs at the time of SCI. Two of them went back to work, with one returning to the same job 84 months after SCI, and the other changing his job 14 month after SCI. There were 4 participants in ASIA C, and 2 of them were students and the others had jobs at the time of injury. One student had continued his study, and one of those who had a job when injured had been unemployed since SCI. In ASIA D group, one was student and 4 had a job at the time of injury. A student discontinued his study since SCI and 2 of those who had a job

returned to the same job as before, and others had been unemployed. Total 8 out of 33 persons started their job again, with mean return time 33 months (SD 24.4).

Table 7. Change of marital status after spinal cord injury

ASIA grade	Marital status	
	Before SCI	After SCI
A (n=16)	9 married	4 divorced or separated 4 married 1 unknown
	7 unmarried	6 unmarried 1 unknown
B (n=8)	4 married	1 separated 2 married 1 unknown
	4 unmarried	3 unmarried 1 unknown
C (n=4)	1 married	1 unknown
	3 unmarried	2 unmarried 2 unknown
D (n=5)	1 married	1 married
	4 unmarried	1 married 3 unmarried

Table 8. Change of employment status after spinal cord injury

ASIA grade	Employment status	
	Before SCI	After SCI (taken time)
A (n=16)	11 employed	1 employed (30 months) 8 unemployed 2 unknown
	5 students	2 student (24 and 60 months) 3 unemployed
B (n=8)	7 employed	2 employed (14 and 84 months) 3 unemployed 2 unknown
	1 student	1 unemployed
C (n=4)	2 employed	1 unemployed 1 unknown
	2 students	1 student (30 months) 1 unknown
D (n=5)	4 employed	2 employed (8 and 14 months) 2 unemployed
	1 student	1 unemployed

DISCUSSION

In this study, SCI due to diving accident occurred most frequently in young male and around one-third of them had advanced swimming or diving skills. C5 vertebra was the most commonly involved fracture level and C4 was the most neurologic level of injury. Swimming pool beside holiday lodge was the most common place diving accidents occurred, followed by swimming pool in sports center and natural bodies of water. The depth of water was mostly less than 1.4 meters, however, there were no depth indicator or diving warning sign in more than half of accident sites. Most of the diving accidents happened in summer and during the day. 5 out of 13 married participants with motor complete injury were divorced or separated after diving accident, and 24% (n=8) of entire participants returned to study or work after an average of 33 months after SCI, while the rate of returning to work was lower in participants with motor complete SCI.

SCI due to diving accident is well known to occur in young males. In this study, 97% were males and 81.8% were under 40 years old, which is consistent with previous studies. Most of victims had skills above intermediate levels and even one third of them had advanced level of diving and swimming skills, and they had no experience taking water safety education before diving, and did not aware of the danger of SCI associated with diving before the injury.

In this study, 70% of diving accidents occurred in summertime, especially in July and August, which is similar results as previous studies reporting more than 70% of the accidents happened in the summer[4, 16].

As for site of diving injury, the results from previous studies varies from region to region. 49% injured in swimming pool in Quebec, Canada, and 17% in Canary island[3, 18]. The study conducted in Pyrenees in France reported that diving accidents exclusively occurred in swimming pools, however, other study conducted in Montopellier in France reported 15% of accidents took place in swimming pool[16, 17]. In our study, 79% (n=26) of diving accidents occurred in swimming pools, relatively higher rate than other studies. This results could be explained by the geographic characteristics in South Korea. In South Korea, more than 70% of land is mountainous, and the nature bodies of the water where people can swim are only small part of the entire coastline. Therefore, it is thought that accidents were lesser common in nature than swimming pools, compared to other countries.

In our study, the most injuries took place in the swimming pool beside holiday lodge, followed by the swimming pool in sports center. The specific circumstances at the time of the injury at these two sites were different. Holiday lodge in South Korea is usually located in good natural places in the countryside and is used with friends or family during holidays or vacations. There is usually a swimming pool beside holiday lodge in South Korea, and its depth is shallow, mostly below the navel of an adult. Although diving in such a shallow water makes it easy for the head to hit the bottom of the pool, most of the swimming pools in holiday lodge had no sign of depth or a diving caution. In addition, four of six participants injured in drunken state had accidents in the holiday lodge. They drank while eating and playing, and injured by diving into the pool with drunken state. Shallow water

depth, not knowing water depth, and alcohol consumption are all risk factors for SCI due to diving accident[3, 19], and all these risk factors were in holiday lodge. However, the specific circumstance of the injury in the swimming pool in the sports center was investigated differently from swimming pool in the holiday lodge. The swimming pool in sports center was more than 1.4 meters deep, with depth indicators. None of participants consumed alcohol, and all of their swimming skills were above the intermediate level. Four of five people injured in sports center had accidents during diving lessons. Most of them were not educated about safety about diving, and they were not aware that diving could cause devastating results. Although there was fewer environmental risk factors compared to the holiday lodge, it was investigated that the personal risk factor was a relatively important, such as ignorance of the possible danger of diving.

Since ASIA grade and NLI are important to the patient's motor function and activities of daily living, they were considered as neurological outcomes of people with SCI due to diving accident. In our study, people with motor complete were 72%, and in particular, about 50% of all participants with ASIA A, and this proportion is similar with other studies when excluding ASIA E[2, 4, 16-20].

In this study, C5 was the most involved fractured vertebra, which is consistent with other previous studies[4, 16-19, 21, 22]. However, the exact NLI varied from study to study. In many studies reported C6 as the most common NLI, but some reported as C4 or C5[2, 17-19, 21, 22]. In our study, C4 was the most common NLI (n=12). We investigated sensory and motor levels of participants with C4 NLI, and two thirds of them had C5 (n=5) or C6 (n=3) motor level with C4 sensory level. Only third of them had C4 level in both motor and sensory

level. Only considering motor level, C5 was the most common motor level (42%, n=14), followed by C6 (27%, n=9).

The reason why around C5 level is the most common fracture involved site or NLI is explained by the mechanism of SCI due to diving accident and the structure of the cervical spine. The most common injury mechanism is extreme movement of the neck at the time of impact to the bottom or some objects, after head-first diving. Because the diver is accelerated when dive into water, it stops abruptly with a sudden impact with floor or objects, and the weight of the body is added at the same time. Because C5-7 segment is the most mobile segment, it causes extreme cervical movement such as hyperflexion, hyperextension, lateral flexion or rotation at this segment, depending on the position or velocity at the time of impact. Moreover, since the C5 vertebral level is the center of the cervical spinal curve, the force applied to the cervical spine is concentrated on C5, and injury is most common at this level. In addition, relatively narrow spinal canal at the mid-cervical segment is explained as the vulnerable reason for this segment[16, 18, 20, 22]. Several studies reported compressive hyperflexion was the most common mechanism of SCI due to diving accident, and burst fracture, which is mainly caused by this mechanism, was the most common type of fracture[16, 18]. In our study, 70% (n=23) of participants had burst fractures, which was consistent with previous reports.

As for socio-professional outcomes, we investigated marriage and employment changes before and after SCI due to diving accident. Because most of participants were relatively young, more than half (52%, n=17) were single and 27% (n=9) were students when injured. As for people with motor complete injury, 13 people were married before injury, but 5 of them divorced or separated. However, there were no change of marital status of people

with motor incomplete injury, except one married after injury. This result was consistent with previous reports that rate of divorce status increased after SCI, and persons with motor functional injuries had less divorce rate than persons with non-motor functional injuries[16, 23, 24].

9% of ASIA A group, 29% of ASIA B group, and 50% of ASIA D group returned to work after SCI. The changes of employment of people in ASIA C group were not investigated because we couldn't get in touch with them. Among 9 students when injured, 3 persons had continued their studies. Persons with motor complete injury had lower rate of return to work, among which it was lower in ASIA A than ASIA B. This result was consistent with previous studies that reported severe repercussion on career including job losses in higher ASIA class[16, 17]. These changes of marriage and employment are great losses not only for individuals but also for entire society.

Previous studies proposed several methods to prevent diving accidents[2, 3, 16, 18, 22, 25]. As for environmental risk factors, they recommended the obligatory installation of diving caution signs and depth indicator when the depth of the water is not deep enough to dive. To manage personal risk factors, widespread publicity and education to raise the awareness of risk of diving is essential. Education programs and campaigns focusing on young males intensely during the summer months should be regularly launched at the beginning of the summer. The program should include not to drink alcohol before diving, and to check the depth of water when playing in the water in an unfamiliar place.

These education and publicity should be done in public schools for larger group of people. There were the projects to educate the risk of diving to students in Canada and Romania[2, 25]. In Canada, there was the project, 'Think First-Sport Smart', aimed to prevent SCI due

to diving among students in high schools. In Romania, there were attempts to provide and extended educational information and qualified scientific explanations in a future scholar curriculum. As such education is not yet provided in South Korea, we suggest it should be considered to implement education and publicity on the dangers of diving in schools. In addition, we also recommend the safety education about risks and precautions of diving must be done before taking swimming or diving class in every sports center.

This study has several limitations. First, there was a time interval between the point of retrospective chart review and the point of telephone interview. Neurologic level and severity were investigated through reviewing electrical medical record, averaged 12.8 months after the injury, however, the survey was conducted on average 46.2 months after the injury. Second, participants were not admitted to our hospitals right after the injury. Most of them were transferred from other hospitals, where they took surgery and rehabilitation immediately after the injury. Therefore, some of examination results including MRI were missed, and it was hard to know the medical and neurologic progression from the day of injury to the time of the investigation. Third, sample size was relatively small, thus further research should be needed, for example, based on national statistics of SCI. Nevertheless of these limitations, our study has strengths. As far as we know, this is the first study reporting the status of SCI caused by diving accident in South Korea. As economy of Korea grows, interest in leisure and sports has been increasing. Thus, the chances of SCI due to diving accident is anticipated to increase, and this study has implications for prevention of SCI due to diving.

CONCLUSION

To prevent further SCI due to diving accident, we suggests that active publicity and education about danger of diving are needed, especially to young population regardless of their swimming or diving skills, and diving warning signs should be beside swimming pool in holiday lodge and sports center, and natural bodies of water such as valleys and beaches. Our study can be used as basic source of education and publicity needed to prevent further SCI due to diving accident, and has implications for the prevention of SCI due to diving in the countries going from developing to developed countries.

REFERENCES

1. Van Den Berg M, Castellote JM, Mahillo-Fernandez I, de Pedro-Cuesta J. Incidence of traumatic spinal cord injury in Aragon, Spain (1972-2008). *J Neurotrauma* 2011; **28**(3)**:** 469-77.

2. Anghelescu A. Prevention of diving-induced spinal cord injuries-preliminary results of the first Romanian mass media prophylactic educational intervention. *Spinal Cord Ser Cases* 2017; **3:** 17018.

3. Barss P, Djerrari H, Leduc BE, Lepage Y, Dionne CE. Risk factors and prevention for spinal cord injury from diving in swimming pools and natural sites in Quebec, Canada: a 44-year study. *Accid Anal Prev* 2008; **40**(2)**:** 787-97.

4. Amorim EC, Vetter H, Mascarenhas LB, Gomes EG, Carvalho JB, Gomes JF. Spine trauma due to diving: main features and short-term neurological outcome. *Spinal Cord* 2011; **49**(2)**:** 206-10.

5. Shingu H, Ikata T, Katoh S, Akatsu T. Spinal cord injuries in Japan: a nationwide epidemiological survey in 1990. *Paraplegia* 1994; **32**(1)**:** 3-8.

6. Acton PA, Farley T, Freni LW, Ilegbodu VA, Sniezek JE, Wohlleb JC. Traumatic spinal cord injury in Arkansas, 1980 to 1989. *Arch Phys Med Rehabil* 1993; **74**(10)**:** 1035-40.

7. da Paz AC, Beraldo PS, Almeida MC, Neves EG, Alves CM, Khan P. Traumatic injury to the spinal cord. Prevalence in Brazilian hospitals. *Paraplegia* 1992; **30**(9)**:** 636-40.

8. Ring IT, Berry G, Dan NG, Kwok B, Mandryk JA, North JB *et al.* Epidemiology and clinical outcomes of neurotrauma in New South Wales. *Aust N Z J Surg* 1986; **56**(7)**:** 557-66.

9. Dahlberg A, Kotila M, Leppanen P, Kautiainen H, Alaranta H. Prevalence of spinal cord injury in Helsinki. *Spinal Cord* 2005; **43**(1)**:** 47-50.

10. Chan CW, Eng JJ, Tator CH, Krassioukov A, Spinal Cord Injury Research Evidence T. Epidemiology of sport-related spinal cord injuries: A systematic review. *J Spinal Cord Med* 2016; **39**(3)**:** 255-64.

11. Kluger Y, Jarosz D, Paul DB, Townsend RN, Diamond DL. Diving injuries: a preventable catastrophe. *J Trauma* 1994; **36**(3)**:** 349-51.

12. Chiu WT, Lin HC, Lam C, Chu SF, Chiang YH, Tsai SH. Review paper: epidemiology of traumatic spinal cord injury: comparisons between developed and developing countries. *Asia Pac J Public Health* 2010; **22**(1)**:** 9-18.

13. Jazayeri SB, Beygi S, Shokraneh F, Hagen EM, Rahimi-Movaghar V. Incidence of traumatic spinal cord injury worldwide: a systematic review. *Eur Spine J* 2015; **24**(5)**:** 905-18.

14. Park CI, Shin JC, Kim SW, Jang SH, Chung WT, Kim HJ. Epidemiologic Study of Spinal Cord Injury. *Journal of the Korean Academy of Rehabilitation Medicine* 1999; **23**(2)**:** 267-275.

15. Lee JS, Kim SW, Jee SH, Kim JC, Choi JB, Cho SY *et al.* Factors Affecting Quality of Life Among Spinal Cord Injury Patients in Korea. *Int Neurourol J* 2016; **20**(4)**:** 316-320.

16. Borius PY, Gouader I, Bousquet P, Draper L, Roux FE. Cervical spine injuries resulting from diving accidents in swimming pools: outcome of 34 patients. *Eur Spine J* 2010; **19**(4)**:** 552-7.

17. Chan-Seng E, Perrin FE, Segnarbieux F, Lonjon N. Cervical spine injuries from diving accident: a 10-year retrospective descriptive study on 64 patients. *Orthop Traumatol Surg Res* 2013; **99**(5)**:** 607-13.

18. Barbara-Bataller E, Mendez-Suarez JL, Aleman-Sanchez C, Sanchez-Enriquez J, Sosa-Henriquez M. [Spinal cord injuries resulting from diving accidents in the Canary Islands]. *Neurocirugia (Astur)* 2017; **28**(4)**:** 183-189.

19. Aito S, D'Andrea M, Werhagen L. Spinal cord injuries due to diving accidents. *Spinal Cord* 2005; **43**(2)**:** 109-16.

20. Korres DS, Benetos IS, Themistocleous GS, Mavrogenis AF, Nikolakakos L, Liantis PT. Diving injuries of the cervical spine in amateur divers. *Spine J* 2006; **6**(1)**:** 44-9.

21. Green BA, Gabrielsen MA, Hall WJ, O'Heir J. Analysis of swimming pool accidents resulting in spinal cord injury. *Paraplegia* 1980; **18**(2)**:** 94-100.

22. Vlok AJ, Petersen J, Dunn RN, Stander J. Shallow-water spinal injuries--devastating but preventable. *S Afr Med J* 2010; **100**(10)**:** 682-4.

23. DeVivo MJ, Hawkins LN, Richards JS, Go BK. Outcomes of post-spinal cord injury marriages. *Arch Phys Med Rehabil* 1995; **76**(2)**:** 130-8.

24. SCI Facts and Figures. *J Spinal Cord Med* 2017; **40**(6)**:** 872-873.

25. Bhide VM, Edmonds VE, Tator CH. Prevention of spinal cord injuries caused by diving: evaluation of the distribution and usage of a diving safety video in high schools. *Inj Prev* 2000; **6**(2)**:** 154-6.

APPENDIX

The manuscript of telephone interview

1. 자기 소개

안녕하십니까? 저는 국립교통재활병원 / 서울대병원 재활의학과 방문석 교수님 밑에서 일하고 있는 전공의 윤재현입니다. 이번에 방문석 교수님께서 한국 내 다이빙 척수 손상환자의 증례 모음이라는 연구를 시작하시게 되어 연락드리게 되었습니다.

2. 본 연구의 배경 및 목적

지금까지 한국에서 다이빙으로 인한 척수 손상 환자 수는 많지 않았지만, 수상 레저 활동의 증가와, 해외여행 중 수상하여 한국에서 치료 받는 경우가 점차 증가하고 있습니다. 이에 다이빙으로 인한 척수 손상의 예방과 관심이 중요성이 점점 커지고 있습니다. 다이빙으로 인한 척수 손상은 주로 경수에 발생하므로, 남은 대부분의 생애 동안 큰 장애를 가지고 살아야 하며, 사지 마비 또는 하지마비 등 운동 관련 문제 외에도, 호흡기, 순환기, 자율신경계, 욕창, 경직, 구축 등 다양한 합병증을 동반하는 경우가 많습니다. 특히, 다이빙으로 인한 척수 손상 환자들은 다른 질병이 없는 건강한, 젊은 사람인 경우가 많아 장애를 지닌 시기가 특히 깁니다. 그 동안 다이빙으로 인한 척수 손상 환자에 대한 문헌은 외국에서 몇 편이 있으나, 아직 한국에서 이에 대해 조사한 바는 없습니다. 이에, 한국에서 다이빙으로 인한 척수 손상의 예방 및 재활을 위한 기초자료를 수집하고자 연구를 시작하게 되었습니다.

3. 참여대상자 및 대상자수

국립교통재활병원에서 진료를 보았던 환자 수는 25명입니다.

서울대병원에서 진료를 보았던 환자 수는 8명입니다.

4. 연구 내용 및 과정

연구에 참여하게 되면, 5~10분 정도 전화를 통해 인터뷰를 진행되며, 이 과정은 녹음될 것입니다. 질문에 답변하거나 연구에 참여하는 것이 불편하신 경우 언제든지 그만두실 수 있습니다

5. 부작용이나 위험 요소

면담 시 특별히 주의해야 할 사항은 없으며, 연구자의 질문에 불쾌함을 느끼시거나 연구에 참여하는 것이 불편하실 경우 도중에 언제든지 그만두실 수 있으며, 즉시 말씀해 주시면 됩니다. 언제든지 연구의 참여를 거부하거나 연구의 참여를 중도에 철회할 수 있고, 이러한 결정으로 인해 연구 참여자에게 어떠한 해나 불이익일 주어지지 않을 것입니다.

6. 참여 시 혜택

연구에 참여 시, 3만원 상당의 기프티콘을 보내드리겠습니다.

7. 개인정보보호 방안

저희는 이 연구를 통해 얻은 모든 개인정보의 비밀 보장을 위해 최선을 다할 것입니다. 이 연구에서 얻어진 개인 정보가 학회지나 학회에 공개될 때 귀하의 이름과 다른 개인정보는 사용되지 않을 것입니다.

연구에 참여하여 주셔서 감사드립니다.

지금부터 약 10분 간에 걸쳐 설문을 진행하겠습니다.

다음은 귀하의 수상 당시 상황에 대한 질문입니다.

1. 수상 장소는 어디입니까? (구체적으로)

주소 : (　　) 도 (　　) 시 (　　) 군 (　　) 구

장소: (　　)

2. 수상 시간은 어떻게 되십니까?

(오전 / 오후) (　　) 시 (　　) 분.

3. 수상 장소가 수영장이십니까?

① 네 ② 아니오

→ 1번을 선택하신 경우, 4-1 문항으로 가주십시오.

→ 2번을 선택하신 경우, 구체적 장소를 적어주십시오. (예: 계곡, 바다 등. 지명 포함)

( )

4-1. 수상 당시 수영장에서 다이빙한 위치는 어디입니까?

① 수영장 모서리

② 수영장 코너

③ 다이빙 보드

④ 기타

4-2. 수영장의 크기는 어느 정도였습니까?

① 25m 이상

② 20~25m

③ 20m 미만

4-3. 수영장 깊이는 어느 정도였습니까?

( ) m

4-4. 수영장 깊이를 알려주는 안내 표지판이 있었습니까?

① 네 ② 아니오

==========

5. 어떻게 다쳤는지 상황을 구체적으로 묘사해주실 수 있으신가요?

(　　head first dive 여부 확인　　)

6. 수상 전 다이빙 관련하여 안전 교육을 받은 적이 있으십니까?

① 네　　(교육은 받은 시간:　　, 장소:　　)

② 아니오

7. 수상 장소에 다이빙 주의 또는 금지 문구가 있었습니까?

① 네　　② 아니오

7-1. 다이빙 사고 후, 수상 장소에서 조치 사항이 있었습니까?

(예시: 문구 설치 여부, 교육 시행 여부 등)

① 네 (구체적 조치 사항:　　)

② 아니오

③ 모름.

8. 다이빙 사고 후 응급실까지 어떻게 이동하셨습니까?

- 사고 후 발견한 사람: (　　)
- 사고 후 발견될 때까지 걸린 시간: (　　)
- 사고 후 응급실까지 이동 수단: (　　)
- 사고 후 응급실 도착까지 걸린 시간: (　　)

9. 수상 당시 귀하의 다이빙 숙련도는 어느 정도였습니까?

① 상

② 중

③ 하

10. 수상 당시 귀하의 수영 숙련도는 어느 정도였습니까?

① 상

② 중

③ 하

11. 수상 전 귀하의 평소 수영 횟수는 어느 정도였습니까?

① 매일

② 1주일에 1~2회

③ 1달에 1~2회

④ 매년 여름에 1~2회

12. 수상 당시 음주를 하셨는지요?

① 네 ② 아니오

12-1. 음주를 하셨던 상태라면, 어느 주종을 얼만큼 드셨는지 적어주십시오.

주종 (예시: 소주, 맥주, 양주, 막걸리…): ( )

양: ( ) (잔 / 병)

13. 음주 외 수상 당시 먹었던 약이나 음료가 있나요? (환각제, 에너지드링크 등)

( )

설문에 잘 참여하여 주셔서 감사합니다.

다음은, 귀하의 사회적인 상황에 대한 질문입니다.

1. 수상 전 직업은 무엇이었으며, 수상 후 직업에 복귀하셨습니까?

수상 전 직업:

수상 후 직업 복귀 여부:

수상 후 직업 복귀까지 걸린 시간은 얼마나 되십니까? ( ) 개월

수상 전과 비교하여, 직장에서의 업무 능력 변화가 있으셨습니까?

1) 변함 없음.

2) 약간 감소

3) 매우 감소

4) 불가능

5) 기타 ( )

2. 귀하의 학력은 어떻게 되십니까?

1) 고등학교 재학

2) 고등학교 중퇴

3) 고등학교 졸업

4) 대학교 재학

5) 대학교 중퇴

6) 대학교 졸업

7) 석사 이상 ( )

3. 귀하는 현재 기혼 상태이십니까?

1) 예 2) 아니오

4. 수상 이후 결혼 생활에 문제가 생기셨나요?

1) 예 (별거, 이혼 등) 2) 아니오

요약 (국문초록)

배경: 한국의 경제가 발전하면서, 레저 및 스포츠 활동에 대한 관심은 늘어나고 있으며, 한국에서 다이빙은 더 이상 외상성 척수 손상의 드문 원인이 아니다. 다이빙으로 인한 척수 손상의 예방을 위해 환자들의 기본적인 정보와 위험 요소에 대한 정보가 필수적이나, 현재까지 한국 내 다이빙으로 인한 척수 손상에 대한 연구는 거의 이루어지지 않았다.

목적: 본 연구는 다이빙으로 인한 척수 손상 환자들의 인구학적 및 신경학적 결과를 기술하는데 목적이 있으며, 사고 당시 상황을 조사함으로써 다이빙으로 인한 척수 손상의 위험 요소를 파악하고자 하였다. 더불어, 사고 전후 결혼 및 직장 변화를 비롯한 재활 결과를 알아보고자 하였다.

방법: 2000년부터 2019년 사이 서울대학교병원 및 2014년부터 2019년 사이 국립교통재활병원에 내원한 다이빙으로 인한 척수 손상 환자들을 대상으로 분석하였다. 전자 의무기록 후향적 분석을 통하여 의학적 및 신경학적 소견을 추출하였고, 설문지를 이용한 전화 인터뷰를 통하여 사고 당시 구체적인 상황 및 사고 전후 사회적인 상태 변화에 대한 정보를 얻었다.

결과: 총 33명의 다이빙으로 인한 척수 손상 환자들이 분석되었으며, 그 중 27명이 전화 인터뷰에 응답하였다. 연구 대상자 중 32명(97%) 은 남성이었으며, 27명 (81.8%)는 사고 당시 40세 이하였다. American Spinal Injury Association A 등급이 16명(48.5%) 으로 가장 흔하였으며, C4가 13명으로 가장 흔한 신경학적 손상 수준이었다. 가장 많이 다이빙 사고가 발생한 곳은 펜션에 있는 수영장으로, 12건(36.4%) 이었다. 사고 당시 결혼 상태였던 완전 마비 13명 중 5명은 사고 이후 이혼 또는 별거하였다. 연구 대상자 33명 중 8명은 사고 발생 평균 33개월 (표준편차 24.4개월) 이후 직장 또는 학업에 복귀하였다.

결론: 다이빙으로 인한 척수 손상은 심각한 기능적 저하뿐 아니라 결혼 및 직업에도 많은 영향을 미친다. 본 연구는 다이빙으로 인한 척수 손상의 예방을 위한 교육 및 홍보를 위한 기본 자료로 활용될 수 있다.

색인: 척수 손상, 다이빙, 위험 요인, 사지마비

학번 : 2019-23243