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Disease Prevalence and Direct, Indirect Exposure to Hazardous Substances among Metropolitan Firefighters in Korea

한국 대도시 소방관들의 유해물질 직접, 간접 노출과 질병유병률

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Soo Jin Kim

Department of Epidemiology
Graduate School of Public Health
Seoul National University

Approved by Committee

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Dissertation Committee ;

Chairman **Sung-Il Cho**

Seung-Sik Hwang

Ki Jung Hong

Seunghon Ham

Joohon Sung

한국 대도시 소방관들의 유해물질 직접·간접 노출과 질병유병률

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지도교수 성 주 헌

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위 원 장 조 성 일 (인)

부위원장 황 승 식 (인)

위 원 홍 기 정 (인)

위 원 함 승 헌 (인)

위 원 성 주 헌 (인)

Abstract

Disease Prevalence and Direct, Indirect Exposure to Hazardous Substances among Metropolitan Firefighters in Korea

Soo Jin Kim
Department of Epidemiology
Graduate School of Public Health
Seoul National University

***Introduction* :** The International Cancer Institute (IARC) under the World Health Organization regulates the occupational exposure of firefighters as group 2B, which is a possible human carcinogenic factor, and group 2A, which is a predicted carcinogenic factor, as the shift work, a factor that disturbs the biological rhythm. In addition, firefighters may be additionally exposed to carcinogens by dangerous substances exposed at fire fighting scene such as disasters. The firefighter's work environment is classified into dispatch scene, emergency response route, and office space. In particular, 10 kinds of toxic substances, such as carbon monoxide, hydrogen cyanide, and formaldehyde, which are generated at the fire scene, which is one of the dispatch scenes, are well known to be one of the strong risk factors that affect human health. Firefighters increase the burden of disease by constantly being exposed to risk factors occurring at the disaster scene. Therefore, if there is information on the risk factors for firefighters' working environment and disaster scene work environment, predictable health effects can be prevented. The purpose of this study is to measure the working environment of firefighters working in metropolitan in the dispatch scene and office space, and to evaluate the health perception of health. In addition, the standardized prevalence rate (ratio) of chronic diseases and work-related diseases is compared and evaluated with the general population with the general population using the results of occupational health examinations targeting the total cohort of firefighters in metropolitan cities to evaluate their health level.

***Methods* :** First, a survey was conducted for 1,097 firefighters working in the city of Seoul for fire fighting and rescue work for 21 days, with a response rate of 40.3%. In this survey, health awareness was evaluated on the use, washing, and management of fire fighting protection suit, one of the personal protective equipment used by firefighters. In addition, the level of activity at the disaster scene among firefighters' work environments was evaluated. In the work environment, the most common occurrence of residential fires in Korea was tested for the type and amount of pollutants for the primary contamination and secondary cross-contamination of fire fighting protection suit. Cross-contamination evaluation was measured by dividing fire clothing into 4 groups according to the degree of risk of the work environment. At this time, 12 items were analyzed through air sampling in

the primary and secondary contamination environment. In addition, the contaminations on the fire fighting protection suit were extracted from the laundry water and water quality analysis was performed on 23 items. In order to prepare countermeasures for problems derived through questionnaire surveys and experimental studies, a specific policy that can increase the feasibility and effectiveness of the Delphi expert survey method was proposed. Participants in the Delphi expert survey conducted three rounds of university professors and firefighters with a priori practical experience and research experience on firefighting scenes and firefighting suits. Second, firefighters evaluated the working environment at the fire station, a waiting space during work. After firefighters withdrew from the fire scene and returned to the fire station, the indoor air quality of the chemically hazardous substances that were secondarily exposed inside the fire station was evaluated. The research subject randomly selected four fire stations located in Seoul, Korea. The two fire stations were measured after the firefighting activities at the fire scene were terminated and returned to the fire station as an experimental group. The other two sites were controls, and the indoor air quality was measured at the usual level regardless of dispatch. We conducted 24-hour monitoring for all fire accidents that occurred in Seoul Metropolitan using fire safety map computer system. Also, indoor air quality was measured immediately after homecoming if the experiment group was to be dispatched due to an accident of intermediate or larger scale. 11 hazardous substance items such as particulate matter, formaldehyde, volatile organic compounds, PAH, VCM, acidity, asbestos, CO_2, NO_2, O_3 were measured according to the process test method. Thirdly, firefighters

classified as one of the dangerous occupations are exposed to unpredictable hazardous substances, but health management is considered a personal obligation. Therefore, in this study, using the results of annual firefighters' occupational health examination, high blood pressure, diabetes mellitus, metabolic syndrome, obesity and work-related diseases such as pulmonary ventilation disorders (limited, obstructive, combined) and noise-induced hearing loss (three tone average and four tone average method). The age- and sex-adjusted standardized prevalence rate per 1,000 firefighters was calculated using the direct standardization method and the age- and sex-adjusted standardized prevalence ratio by the indirect standardization method.

***Results* :** In the first study, firefighters had a high 94.4% awareness of the possibility of carcinogens occurring at the disaster scene. It was confirmed that these health awareness did not affect the behavior of the use, washing, and maintenance of fire fighting protective suit that protects their own safety. However, in the use of fire fighting protection suit, there was statistical significance between the thought of the location where fire fighting protection suit should be taken off after the firefighting activity at the fire scene and the health awareness. As a result of the fire scene and fire fighting protection suit contamination assessment, hydrogen cyanide, which causes acute skin toxicity, was detected in both incomplete and complete combustion at the fire scene. Hydrogen cyanide was also detected in the air sampled in fire fighting protection suit, confirming the importance of wearing fire fighting protection suit at the fire scene. Formaldehyde was detected in fire fighting

protection suits exceeding the exposure limit TWA 0.3 in complete combustion. In addition, hydrogen cyanide and nickel were detected in newly allocated fire protection clothing, but did not exceed the risk level. Hydrogen cyanide was detected in all experimental groups in fire fighting protection suit, and heavy metals such as lead, iron oxide, aluminum and cadmium were also detected in air sampling. In the results of water quality analysis for cross-contamination of fire fighting protection suit, four items of copper and its compounds, antimony, acrylonitrile, and diethylhexylphthalate were detected in excess of the standards applied to wastewater discharge facilities for specific water quality hazardous substances according to the Water Environment Conservation Act in Korea. As a result, it was confirmed that the contamination of fire fighting protection suit at the fire scene was serious and suggested the possibility of water pollution. In addition, it was confirmed that policy measures were necessary as four items were detected exceeding the wastewater standard. The most urgent task was to secure the budget for the relevant field and conduct education on the risk of health impact of contaminations in the disaster scene in the importance category of the questionnaire survey and the results of the fire scene and fire fighting protection suit contamination level test. In the field of feasibility, education on the risk of health impacts of pollutants at disaster scenes, first-line decontamination education for personal protective equipment, improvement of personal protective equipment management system such as fire fighting protection suit and development of a curriculum for systematic operation were evaluated as the most urgent tasks. In the second study, it was confirmed that three of the 11 hazardous substances measured by the fire department exceeded the domestic and foreign standards, and one was close to the international standards. In particular, total volatile organic compounds, carbon dioxide and sulfuric acids were 2.5 times, 2.2 times and 1.1 times higher than the standard. Also, for formaldehyde and sulfuric acid, it was measured higher in the control group than in the case group. In the third study, as a result of comparison with the general population using the data obtained from occupational health examinations for firefighters in metropolitan cities, the age- and sex- adjusted standardized prevalence rate at the disease stage was 12.43% (male 16.91%, female 7.76%) for metabolic syndrome in firefighters, and in pulmonary ventilation disorders, the restrictive was 16.87% (male 15.45%, female 18.32%), and the combined was 2.07% (female 2.59%), which was higher than that of the general population. The general population was hypertension 17.93% (male 23.44%, female 12.19%), diabetes mellitus 5.30% (male 6.75%, female 3.80%), obesity 34.29% (male 46.94%, female 21.14%), and in the case of pulmonary ventilation disorder, obstructive 4.39% (male 6.13%, female 2.61%), in the case of noise-induced hearing loss by three tone average, the right side was 4.41% (male 5.51%, female 3.29%), and the left side was 4.87% (male 6.41%, female 3.29%). In the four tone average, the right side was 6.99% (male 8.66%, female 5.28%), and the left side 7.92% (male 10.06%, female 5.71%) higher than that of firefighters. The age- and sex- adjusted standardized prevalence rate for each disease was hypertension 37.26% (male 52.45%, female 21.47%), diabetes mellitus 23.17% (male 30.79%, female 15.25%), metabolic syndrome was 87.21% (male 83.09%, female 91.49%)), obesity was 23.25% (male 33.08%, female 13.03%), which was higher in all firefighters than the general population. In addition, in the standardized

prevalence ratio by indirect standardization, in the case of the disease stage, the firefighters were obesity 1.12 times (95% CI 1.08-1.16) and the metabolic syndrome 1.33 times (1.26-1.40) higher than the general population. It was higher than that of the general population (1.29-1.40), hypertension 1.89 times (1.83-1.96), diabetes mellitus 1.36 times (1.31-1.41), and metabolic syndrome 1.85 times (1.81-1.90).

Conclusions **:** There was no statistical significance between the firefighter's health awareness and the use, washing, and management behavior of firefighters through the fire fighting protection suit survey. However, there was statistical significance between the health awareness and the thoughts on the proper use of fire fighting protection suit. Therefore, it is necessary to provide a pathway to move from thought to action. Firefighters' working environment at the disaster scene was measured through experiments on the occurrence of contaminants in fire scenes and fire fighting protection suits that may occur in residential fires. Through the results of this study, we were able to estimate the types and amounts of hazardous substances that can occur in a residential fire. Based on the results of this study, it is possible to establish a database on the types and amounts of hazardous substances that generally occur at residential fire scenes. Furthermore, it was confirmed that follow-up research and policy implementation are necessary through confirmation of the possibility of water pollution due to contamination of fire fighting protection suit. Also, if there is information on the number of years worked and the number of dispatches of firefighters, the cumulative exposure amount of hazardous substances exposed at the residential fire scene can be calculated. These data can be used as

evidence to prove whether a firefighter has a disease related to work when a disease occurs. In addition, it will be able to provide a strong scientific evidence for implementing firefighting policies for emergency decontamination on-scene for firefighting suits with cross-contamination at the fire scene. The results of this study can be actively used when promoting the safe use of firefighters' fire fighting protection suit and health policies. Through the evaluation of the indoor air quality of the fire station building, the work environment was measured for the firefighter's standby working environment, and items exceeding the standard were detected in the indoor space and garage. In addition, regardless of returning after dispatch to the disaster scene, the accumulation of fire fighting vehicle exhaust gas and usual chemically hazardous substances has the potential to affect not only the indoor air quality of the building, but also the health of firefighters in the long and short term. It was confirmed that air quality management was necessary. The results of this study suggest that the indoor air quality management system in the Seoul Fire Department can be used for settlement and improvement in the future. Finally, by comparing the standardized prevalence rate between firefighters and the general population through the analysis of the results of occupational health examination, it was possible to estimate that there is an effect of healthy workers in the case of the disease stage. However, in the case of the pre-disease stage, it was confirmed that a systematic health management program was necessary as firefighters showed a higher prevalence than the general population in all chronic diseases. In particular, it is necessary to establish a systematic tracking and management system through research through cohort establishment of examination results in occupational groups showing the effect of healthy workers.

Keywords: Firefighter, Working environment, Direct & Indirect Exposure, Health awareness, Standardized prevalence rate (ratio), Chronic & Work-related disease, Epidemiology

Student Number: **2009-30659**

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Chapter Ⅰ. Introduction

1.1 Background

Firefighters are one of the dangerous occupations working in extreme environments. It is exposed to various physical hazards such as heat exposure from fire fighting work such as fire at various disaster scenes, vibration and noise during rescue work . In addition, there is exposure to chemical hazards due to toxic substances generated from fire, and the types of chemical substances exposed depending on the substance causing the accident are very wide.

1.2 Burden of Occupational Disease and Injury among Firefighter

In United States of America, fulltime working firefighters have the second highest injury rates among emergency responders [1]. In 2012, the 1.1 million career and volunteer firefighters suffered an estimated 69,400 injuries, a rate of 6.1 injuries per 100 firefighters in USA [2, 3]. National Fire Protection Association (NFPA) estimates that there were an estimated average of 30,290 fireground injuries per year from 2010 to 2014 and 27,020 fireground injuries in 2014 represents the lowest fireground injury count in the 10 years since 2005 [4]. One-third of the injuries resulted in lost work time and were classified as either moderately severe (30%) or severe (2%) injuries [2, 4]. The leading cause of firefighter fireground injuries was overexertion, strain, accounting for 26% of the total, followed by exposure to hazard, with 21% of the injury total [5]. Other leading causes of injury included slip or trip (13%), contact with object(13%), fall(11%), and being struck or assaulted by person, animal, or object (7%). The majority of injuries (68%) were classified as minor. The majority of firefighter injuries were sustained by career firefighters (79% of the total) [2, 4].

According to the world health organization (WHO), firefighters are classified as occupational groups with a high risk of exposure to post-traumatic stress disorder (PTSD) because of the high frequency of exposure to trauma events [6]. Irregular working hours and shift work have been linked with insomnia, cancer, ischemic heart disease, and multiple sclerosis [6, 7].

1.3 General review on Description of Job Current Distribution and Occupational Environment of Firefighters in South Korea

78% of firefighters working in metropolitan cities work in three groups and two shifts, and they work an average of 56 hours per week. The shift work pattern is cycled every 21 days. Working hours vary by type. Day shift is 9 hours from 9:00 to 18:00, night work is 15 hours from 18:00 to 9:00 the next day, and shift work is performed 24 hours from 9 am to 9 am on the day.

The duties of firefighters are very diverse, and the working environment is somewhat different depending on the job duty. The specific performance details and working environment for each job duty are as follows ;

1.3.1. Fire suppression and Fire investigation worker

Fire suppression is a fire scene activity that minimizes damage caused by fire and suppresses or extinguishes fire at the fire scene. When the destructive fire goes out, it checks whether there are any remaining fire, and this is called fire overhaul. In this way, the fire fighter patrols for fire prevention, inspects firefighting water such as hydrants, and extinguishes fires in case of fire. First, fire investigation personnel carry out tasks such as data collection, questioning on related parties, scene verification, identification, assessment, and experimentation to identify the cause of the fire and calculate the damage caused by the fire. Second, for the determination of the cause of the fire, the specific factual relationship is clearly identified through a comprehensive judgment mainly based on vision, utilizing specialized knowledge, skills, and experience. Third, it conducts necessary experiments by scientific method on all related sites such as the formation, structure, material, composition, and properties of objects related to fire, and identifies the cause of the fire based on the results. During this process, both firefighters and fire investigation personnel are exposed to various combustion substances and toxic gases, and health effects are affected.

1.3.2. Rescue worker

As a firefighter belonging to the 119 Rescue Team and performing lifesaving as the top priority, they perform search and rescue of lives at disaster and various accident scenes. In the firefighting aviation team, rescuers board fire helicopters and perform basic emergency medical services for aviation rescue and hospital warfare. They have received various professional education and training related to rescue and emergency rescue such as urban exploration and rescue, disaster rescue, mountain rescue, vehicle rescue, chemical emergency rescue, and emergency rescuers, and hold relevant qualifications. In addition, people search and rescue life at various disaster scenes such as fire. In this process, like firefighters, they are exposed to various combustion materials and toxic gases, and they are affected by health. In particular, rescuers are exposed to a higher risk of burns than firefighters.

1.3.3. Emergency Medical Service (EMS) worker

119 EMS teams are deployed and operated under the fire department of 18 provinces and provinces, based on the 119 Rescue and Emergency Medical Services Act, the rules on fire fighting power standards. When receiving an emergency report order, one emergency driver and one or two emergency technicians will be dispatched. This is due to differences in manpower and budget for each local governments.

Ambulance crews are required to perform a series of measures, such as counseling, rescue, transfer, and first aid, for emergency patients in the process from the occurrence of the emergency patient in the pre-hospital stage until recovery from the risk of life or the removal of serious physical and mental status.

1.3.4. Emergency Dispatching and Communication worker

Emergency dispatching is gate keeper of emergency service system and first chain of emergency persons management in general emergency situation. Also, emergency dispatching is the first to be allocated one of emergency resources for all emergency response. The 17 provinces have a single centralized dispatch system for the whole population and for ambulance services but 1 city have multiple localized dispatch at fire department due to electrical and informative system overloading. Dispatch center receives calls for fire, rescue, EMS, and other safety incident including hazard material (HAZMAT) incident. National statistic of emergency and disaster related call from 119 fire emergency operation center is total 11,567,173 cases in 2019. The number of dispatch-related emergency filings received is 4,375,325 cases and other information guide, complaints, prank calls are 7,191,848 cases. Of these, emergency response frequency of fire, rescue and emergency patient response call was 340,757 cases (2.9%), 635,996 cases (5.5%), 2,684,775 cases (23.2%), respectively. The nationwide average number of call per year is approximately 3,720,000 including 80% for EMS and 20% for other reasons.

1.3.5. Fire Administration worker

The fire administration performs administrative support in order to perform smooth field work such as emergency dispatch in case of a disaster such as a massive fire, mass casualty incident, disaster, building collapse, etc. Specifically, there are reorganization and operation of firefighting organizations, recruitment of personnel, budget planning and budget execution, purchase of firefighting equipment and firefighting vehicles, inspection of firefighting targets for fire prevention, approval and approval of new construction targets, operation and support of dispatch personnel.

1.3.6. Incident Safety Office (ISO) worker

With the enactment of health and safety management regulations for firefighters in 2008, firefighters started to take charge of on-scene safety and health work at firefighting activities. The on-scene safety inspector is in charge of securing the health and safety of firefighters working in the field and assisting the on-scene commander. In addition, plans for health promotion and safety accident reduction, implementation, accident analysis, field investigation, intervention, evaluation, and feedback are performed. However, due to the difficulty of recruiting manpower, it is not possible to secure a separate manpower for the performance of the on-scene safety inspector.

1.3.7. Fire Engine Drive worker

Firefighting vehicle drivers perform driving tasks at the same time as in charge of fire, rescue, and emergency services at various accident scenes. They performs the role of supporting firefighting activities such as manipulating firefighting vehicles and procuring equipment, rather than performing actual fire suppression and lifesaving at fire scenes and rescue scenes. However, the ambulance driver assists the paramedics to perform pre-hospital emergency treatment such as cardiopulmonary resuscitation (CPR), bleeding control, and spinal immobilization at the scene of emergency patient occurrence. In addition, they regularly perform vehicle maintenance to ensure that all types of fire fighting vehicles are available 24 hours a day.

1.4. Health-related Risk Factors of Occupational Environment among Firefighters

Firefighters are exposed to various psychological, physical, chemical, and biological hazards in the process of performing fire, rescue, and emergency medical services at various accident scenes such as disasters. Hazardous factors of exposure include chemicals generated during the fire combustion process, physical factors such as heat, infrared rays, noise, working stress, and mental and physical stress from shift work.

They are constantly exposed to noise from fire engine sirens, engines, radio communications, and firefighting equipment. Hearing tests for firefighters showed higher hearing thresholds at 3,000 Hz, 4,000 Hz, and 6,000 Hz, compared to the control group of the same age group in the general population.

Firefighters are exposed to violence while performing field work. Of these, Paramedics are exposed to a higher risk of violence in firefighting scenes than other service personnel.

1.5. Firefighters' risk of exposure to toxic substances at fire scenes and health effects

Firefighters are exposed to 10 kinds of chemically hazardous substances, such as carbon monoxide, carbon dioxide, acrolein, hydrogen cyanide, nitrogen oxides, and formaldehyde, which are generated in the event of a fire in the long and short term. As a result, there is a risk of developing acute and chronic health disorders including cancer, cerebro-cardiovascular and respiratory disease. Hazardous chemicals exposed by firefighters at fire scenes are mainly gases and particles, which are combustion by-products. Most buildings are constructed of natural and synthetic materials, so when a fire occurs, materials such as wood, paint, adhesives, plastics, furniture, carpets, and numerous synthetic materials included in insulation are burned together. Combustion by-products and various toxic gases generated here lead to death or affect the eyes, respiratory system, and skin. However, it is very difficult to know exactly all the types of harmful substances generated in the fire extinguishing process. In addition, there are few databases in Korea that quantitatively measure and measure these harmful substances. Therefore, actual firefighters have not been able to accurately evaluate what harmful substances and how much they are exposed to by type of substances causing fire.

1.5.1. Health effects from skin, respiratory exposure to hazardous substances

In a study conducted in Ottawa, Canada, the concentration of PAHs metabolites in the human body was measured before and after fire suppression in 19 real fires in 45 firefighters. As a result of using hazardous substances isolated from skin samples, it was confirmed that the detection amount of PAHs metabolites increased by 2.9~5.3 times. In addition, as a result of performing Ames test (Salmonella mutagenicity assay) using harmful substances isolated from skin samples, it was confirmed that the risk of mutation induction was increased by 4.3 times [8].

Fent et al. (2014) measured the skin exposure of firefighters to PAHs through two simulated fires, such as a wood fire and a container fire, with the help of the Illinois Fire Department, USA. As a result, it was confirmed that PAHs were highly detected in the neck, scrotum, and face in both primary and secondary. In particular, the scrotum part is a part that is thought to be difficult to inflow of external air when completely wearing fire protection clothing. As a result of the experiment, as large amounts of PAHs are detected in the scrotum area, it is thought that harmful substances are sufficiently blocked through wearing personal protective equipment during firefighting activities, but exposure to harmful substances through the skin is estimated to be overlooked. In addition, in this area, firefighters not only in Korea but also overseas, it is a part that requires health awareness of their working environment. In particular, high levels of PAH metabolites were detected in urine 6 hours after the end of the experiment. As a result, it was confirmed that it is important to quickly remove contaminants exposed to the skin surface after the end of the fire scene activities [9].

Stec et al. (2018) confirmed for the first time in the UK that firefighters were exposed to occupational exposure to hazardous substances such as PAHs. It was confirmed that skin exposure to PAH is widely occurring, especially in the hands and neck. As a result of exposure for about 60 minutes in a simulated fire test using a container, the exposure concentration was high in the order of the hand, the front part of the neck and the back part. In addition, as a result of exposure to personal protective equipment, the exposure concentration was high in the order of SCBA, fire protection shoulder, and protective gloves. The exposure to PAHs and cancer risk were analyzed using cancer slope factors (CSF) used to predict cancer risk. As a result, PAHs accounted for 20% of skin absorption. As a result of analyzing cancer incidence per 100,000 people, the amount of harmful substances exposed to the neck and hands was as high as 7 to 25 persons per 100,000 persons [10].

Wingfors et al (2018) analyzed the correlation between skin exposure of Swedish firefighters and biomarkers in urine. Skin exposure and urine analysis of 22 types of PAHs were performed on a total of 20 firefighters. After exposure, 14-PAHs in the skin increased 5 times and 1-hydroxypyrene in urine increased 8 times. In particular, the relative increase between the accumulation of pyrene in the neck and 1-hydroxypyrene was analyzed after 6 hours of exposure. As a result, it was confirmed that the increase due to skin exposure has a much higher correlation than the value due to exposure to the skin and other pathways. This means that the influx of PAHs through skin exposure is greater than the respiratory route [11].

Fabian et al evaluated the degree of exposure of firefighters to gaseous and particulate matter in the fire scene and in the process of overhaul. Hazardous substances deposited on the surface of equipment used by firefighters were analyzed through wipe sampling. As a result, various harmful substances were detected, from gloves to carcinogenic heavy metals, PAHs, and phthalates, which are well known as environmental hormones. Rather than direct exposure opportunities, it was confirmed that there is a risk of further exposure due to flying substances blown into the air during the process of shaving or handling gloves [12].

1.5.2 Cancer incidence by hazardous substances exposure among firefighters

The International Agency fir Research on Cancer (IARC) reviewed about 42 documents that applied various epidemiological designs to evaluate the carcinogenic potential of firefighters. In the existing epidemiologic studies, firefighters are exposed to a number of harmful substances including various carcinogens at the actual scene. Nevertheless, it was evaluated that there was a clear limitation that they could not take into account their exposure range and level. In other words, in some studies, firefighters tended to increase some cancers than the general population, but it was judged that it was difficult to expose consistent patterns due to severe exposure variation. Despite these limitations, meta-analysis showed that firefighters tended to increase some types of cancer [13, 14]. In particular, in the three types of cancer, the relative risk was constantly increasing, and the average tendency of increasing was statistically significant. Of the three cancers, the first testicular cancer had an increased risk in all six studies, with an average relative risk ratio of 1.5. The second prostate cancer had an increased risk in 18 of 21 studies, with a relative risk ratio of 1.3. Finally, the risk of non-Hodgkin's lymphoma increased in 5 of 6 studies, and the average relative risk ratio was 1.2 [14].

In the Philadelphia firefighter cohort study, followed up from 1985 to 2009, the standardized incidence of cancer was 1.09 times (1.06-1.12) higher than that of the general population. Esophageal cancer was 1.62 times (1.31-2.00), mesothelioma 2.29 times (1.61-3.19), kidney cancer 1.27 times (1.09-1.48) higher than the general population, and the standardized cancer mortality rate was 1.39 times (1.14-1.67) and 2.0 times (1.03-3.49), 1.29 times (1.05-1.58), respectively. In other epidemiologic studies, the incidence of colorectal and rectal cancer was higher [15-19], and the risk increased with longer working and incubation periods [19, 20].

San Francisco firefighters, employed between 1940 and 1970, had a liver cancer mortality rate twice that of the general population (41), but other studies did not show significant results [15, 16, 19, 21].

Bates, M. N. et al (2007) analyzed the enrollment cancer data of men registered in California from 1988 to 2003. As a result, firefighters reported odds ratio with scrotal cancer 1.54 (1.18-2.02), melanoma 1.50 (1.33-1.70), brain cancer 1.35 (1.06-1.72), esophageal cancer 1.48 (1.14-1.91), prostate cancer 1.22 (1.12-1.33), respectively [22].

R.D. Daniels et al (2015) confirmed that there is a causal relationship between fire suppression time, cancer prevalence, and cancer mortality in a study conducted on US firefighters. At the same time, it was confirmed that there was a correlation between mortality due to leukemia and fire outbreaks, and lung cancer incidence had a linear relationship with the accumulated amount of fire exposure [23].

1.5.3. Overseas Firefighter's Presumptive Cancer Legislation

In foreign countries, such as the United States, Canada, and Australia, when firefighters get cancer, the state operates a system that proves the relationship with the job. If the firefighter's job is not related to cancer, the basic principle is that the state, not the firefighter, should prove this fact [24].

In the mid-1990s, in Canada, epidemiologic investigations on cancer and disease were conducted on 6,000 firefighters who worked at six fire departments. As a result, death from brain cancer was statistically significantly higher in firefighters, and respiratory, cardiovascular and digestive systems were found to have a relatively high risk of disease. Based on the results of this study, Ontario, Canada, has prepared guidelines for handling accident recognition cases for brain cancer and leukemia occurring in firefighters in 1999. This action was an important first step towards addressing the official actions of firefighters for occupational diseases. In May 2002, the Manitoba provincial government enacted the first putative cancer law for firefighters in Canada, and in 2003 Alberta also enacted a law. Legislation enacted in these two states later became the base model for putative cancer legislation in other states. In the case of Ontario, legally recognized cancer types in 2014 expanded from 8 to 14 (Ken G. Block, 2014). Alberta has 17 types of cancer recognized. In Canada, as of April 2020, 13 states have put into effect presumptive cancer legislation. In addition to cancer, heart disease, infectious disease, and behavioral health are also being applied (Table 1-1).

Table 1-1. Canadian presumptive disability laws by provinces[1]

Province	Heart Disease	Lung Disease	Cancer	Infectious Diseases	Behavioral Health
Alberta	✓		✓		✓
British Columbia	✓		✓	✓	✓
Manitoba	✓		✓		✓
New Brunswick	✓		✓		✓
Newfoundland			✓		✓
Northwest Terr.	✓		✓		
Nova Scotia			✓		✓
Nunavut Terr.	✓		✓		
Ontario	✓		✓		✓

[1] https://www.iaff.org/presumptive-health/#1555251949878-136a2ffb-5bb7, (accessed November, 2020)

Province	Heart Disease	Lung Disease	Cancer	Infectious Diseases	Behavioral Health
Prince Edward Island	✓		✓		
Quebec	-	-	-	-	-
Saskatchewan	✓		✓		✓
Yukon Terr.	✓		✓		✓
Total	10	-	12	1	9

The United States enacted the first firefighter cancer estimation law in California in 1982, and since then other states have steadily expanded the legislation. The laws vary slightly from state to state, and there are also differences in the types of cancer the laws cover. As of April 2020, 50 states have designated occupational diseases for heart disease, lung disease, infectious disease, and behavioral health in addition to cancer (Table 1-2).

Table 1-2. American presumptive disability laws by states[2]

State	Heart Disease	Lung Disease	Cancer	Infectious Diseases	Behavioral Health	Other
Alabama	✓*	✓*	✓	✓*		
Alaska	✓	✓	✓			
Arizona	✓		✓		✓*	
Arkansas			✓			

[2] https://www.iaff.org/presumptive-health/#1555251949878-136a2ffb-5bb7, (accessed November, 2020)

State	Heart Disease	Lung Disease	Cancer	Infectious Diseases	Behavioral Health	Other
California	✓		✓	✓	✓	Hernia
Colorado	✓*		✓	✓	✓*	
Connecticut	✓		✓*	✓*	✓*	
Delaware						
Florida	✓		✓	✓	✓*	
Georgia			✓*			
Hawaii	✓	✓	✓*			
Idaho	✓*	✓*	✓	✓*	✓*	
Illinois	✓*	✓*	✓	✓*	✓*	Hernia/Hearing
Indiana	✓	✓	✓			Parkinson's
Iowa	✓	✓	✓	✓		
Kansas	✓	✓	✓			
Kentucky			✓*			
Louisiana	✓	✓	✓	✓	✓	Hearing
Maine	✓	✓	✓	✓	✓	
Maryland	✓	✓	✓			
Massachusetts	✓	✓	✓			
Michigan	✓	✓	✓			
Minnesota	✓		✓	✓	✓	

State	Heart Disease	Lung Disease	Cancer	Infectious Diseases	Behavioral Health	Other
Mississippi			✓*			
Missouri	✓	✓	✓	✓		
Montana	✓		✓			
Nebraska	✓	✓	✓	✓	✓*	
Nevada	✓	✓	✓	✓	✓*	
New Hampshire	✓	✓	✓		✓	
New Jersey	✓	✓	✓			
New Mexico	✓		✓	✓	✓	
New York	✓*	✓*	✓	✓	✓*	
North Carolina			✓*			
North Dakota	✓	✓	✓	✓		
Ohio	✓	✓	✓			
Oklahoma	✓	✓	✓	✓		
Oregon	✓	✓	✓		✓	
Pennsylvania			✓	✓		
Total	42	34	48	27	22	

1.5.4. Establishment and operation of carcinogenic substance exposure database

In some countries, data on carcinogens among hazardous substances that can be exposed to firefighters are separately managed. Canada's CAREX (CARcinogen Exposure) is a representative example. In Canada, exposure data for hazardous substances is managed through CEREX. CAREX was initiated by the Finnish Institute for Occupational Health. In the European Union, the CAREX database was built by integrating information on existing carcinogens centering on the affiliated countries, and in Canada, CAREX in Canada was developed to suit its own situation (Figure 1-1) [25]. In particular, it provides summary information on carcinogens that can be exposed to representative dangerous occupations, and firefighters are included in this list. Briefly, as classified as Group 1 by the International Cancer Institute, the representative carcinogens that can be exposed to firefighters are asbestos, benzene, diesel emissions, ethylbenzene, formaldehyde, PCB (polychlorinated biohenyl), PAHs, and ultraviolet rays from sunlight. CAREX in Canada provides a caicinogen profile for carcinogens that can be exposed, including information on the use, production, transport, exposure routes, and health effects of carcinogens. Data registered in the Canadian workplace exposure database is used to assess the exposure level of carcinogens, but it is known that firefighters' records of carcinogen exposure are very limited in Canada. In other words, the exposure level of carcinogens of firefighters can vary in various ways depending on variables such as ventilation status, wind, temperature, time spent at the fire site, fire site work place, firefighter's duty, and fire type. We believe that quantitative evaluation has fundamental limitations. Nevertheless, the fact that some data that can be used for evaluating the exposure risk of firefighters is constructed and retained is a major difference from the Korean situation and a lesson to us [25].

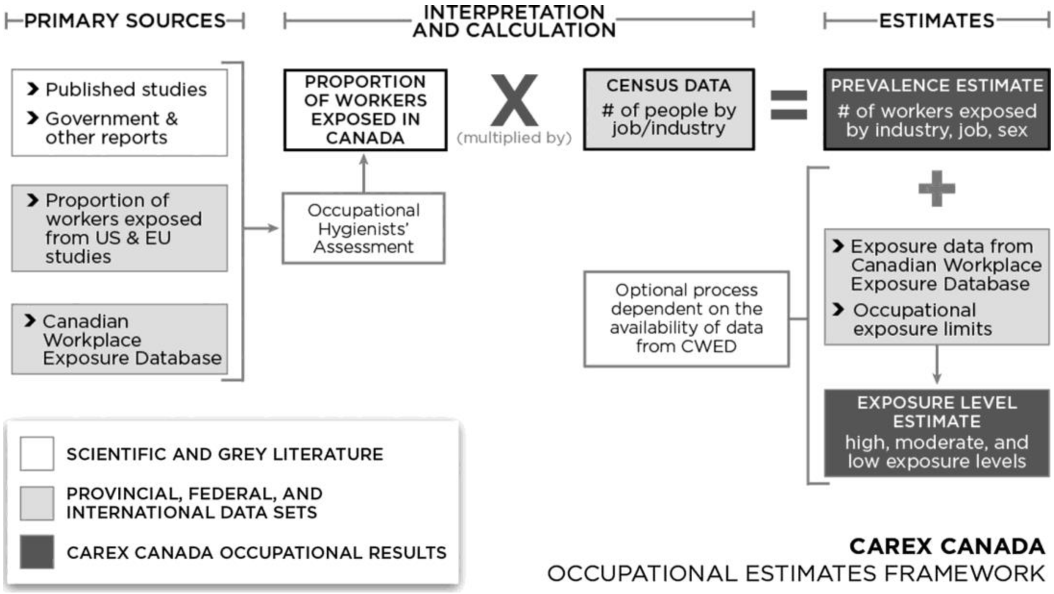


Figure 1-1. Generalized methodology used to generate estimates of occupational exposure to known and suspected carcinogens by CAREX in Canada **(**CAREX Canada: an enhanced model for assessing occupational carcinogen exposure)

1.6. Firefighters' Health Perception and Behavior in Disaster Scenes

Research on the relationship between behavior and health accidents at disaster scenes such as fires targeting professional firefighters has not been carried out. A comparative study on the use, cleaning, and storage of equipment between volunteers and career firefighters conducted in Kentucky, USA, was recently conducted. In the study results, there was no statistical significance between the two groups of volunteers and career firefighters [26]. In addition, behavioral evaluation studies related to equipment cleaning, storage, and disposal were conducted between volunteers and career firefighters in the same area. In this study, it was found that most of the study participants (88%) felt susceptibility to diseases such as cancer and respiratory diseases. However, there are no studies showing the relationship between the behavior of firefighters, who are career personnel in the disaster scene, and their thinking about health accidents, so this research needs to be carried out in the future [27].

1.7. Firefighter Occupational Health-related Law and Regulations in South Korea

In August 2012, the Basic Law on Health, Safety and Welfare for Firefighters was enacted with the aim of improving the working conditions of firefighters, improving the quality of life, and improving the quality of firefighting services. With the implementation of this Act, the Commissioner of the Fire Department establishes a basic plan for health, safety and welfare for firefighters every five years, and based on this, establishes a plan for each year to implement the policy. The contents included in the establishment of the basic plan are as follows ; basic goals, direction of implementation, related research, improvement of working conditions for firefighting officials, occupational health examination and mental health management, treatment and life stability support for firefighters injured or sick due to firefighting accidents, installation of welfare facilities and physical fitness facilities operation, financing and operation.

For the health management of firefighters, medical institutions can be designated and operated as occupational firefighting treatment centers, and operating expenses are borne by the state or local governments. In order to prevent safety accidents during firefighting activities, it is prescribed to appoint a health and safety manager at the fire department. In addition, firefighters are required to have or entrust firefighters for health management, counseling, and mental health programs. Training is provided to prevent exposure to harmful factors or safety accidents during firefighting activities at various disaster scenes. In order to protect the health of firefighters from harmful factors at the disaster scene, it is prescribed to measure the firefighting work environment, but it is classified as a discretionary provision, so it is hardly implemented. Firefighters are required to undergo occupational health examination once a year to protect their health, and when a health problem occurs, they are required to change their position and take measures for disease treatment.

The regulations on health and safety management for firefighters were enacted in 2008 as an order of the Fire Department. It aims to proactively promote the safety and health of firefighters by determining necessary matters related to the prevention of firefighters' safety accidents and health and hygiene. This regulation this following includes ; Organization of firefighters' health and safety at firefighting scenes, education and training, physical strength management, infection prevention, health examination, epidemiologic investigation of occupational diseases, on-scene firefighting activities harmful factors management, operation of health and safety management system.

In order to strengthen and systematically manage firefighters' on-scene safety management, the safety field was subtracted from the existing firefighter health and safety management regulations. The purpose of this article is to regulate matters related to safety management of firefighters' on-scene firefighting activities, and the scope of application is as follows ; 1) Matters related to the safety management organization and its duties 2) Matters related to safety training for on-scene firefighting activities 3) Matters related to safety management for on-scene firefighting activities 4) Matters related to the investigation and establishment of countermeasures for on-scene firefighting activities 5) Other firefighters on-scene Matters concerning safety management of firefighting activities.

In this case, DB construction, analysis, evaluation, and training processes are included in order to find out the cause and prepare systematic countermeasures for safety accidents and traffic accidents of firefighters that occurred during field activities. In addition, it includes contents to further strengthen on-scene activities through the assignment of personnel in charge of on-scene safety during on-scene fire fighting activities in all cities and provinces.

Chapter Ⅱ. Behavior Evaluation of Firefighters′ Turnout Gear Using, Management and Assessment of Direct & Cross Contamination through Chemical Pollutant Exposures after Fire Occurrence

2.1 Introduction

The National Fire Agency (NFA) reports that there were approximately 55,964 firefighters in the South Korea in 2020. Of these South Korea firefighters, 25,346 (45.3%) were fire suppression and investigation related task firefighter and fire-rescuer, emergency medical service (EMS) provider, emergency communication, administrator were 5,346 person (9.6%), 10,698 person (19.1%),1,398 person (2.5%), and 13,176 person (23.5%), respectively [28]. Firefighters are repeatedly exposed to chemical hazards from physical hazards, such as exposure to heat due to life search, rescue, fire suppression and fire investigation, and various toxic substances from fires [12]. Firefighters are also exposed to psychological risks from work conditions such as shift work and emergency dispatch, as well as health risks including cancer [6, 14].

Firefighters inhale or absorb harmful by product such as carbon monoxide, hydrogen cyanide and combustion by products such as heavy metals, or absorb them into the skin as they work at the fire scene. Firefighters are repeatedly exposed to a variety of known hazardous material including carbon monoxide, formaldehyde, hydrogen cyanide (HCN), polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs) and situation from both residential and industrial fires [12, 29]. Also, exposure to these substances has been linked to increased health-related risk which is lung cancer, gastric, brain, prostate, kidney, and testicular cancer, mesothelioma, myeloma, non-Hodgkin lymphoma. In particular, in has been found in recent studies that firefighters have a higher exposure weight through skin than exposure fire fighting personnel protective equipment (PPE) such as fire fighting protective suits (outer and inner shell), helmet, protective hoods, eye protection, face masks and goggles, footwear, glove, self contained breathing apparatus (SCBA) [9, 29, 30]. This is guided by NFPA 1971 standard on protective ensembles for structural fire fighting proximity fire fighting [31]. In addition, the standards for wearing personal protective equipment worn by firefighters are stipulated in the firefighter health and safety management regulations in Korea.

Hazardous substances generated from fire scene enter the body mainly through various routes such as respiratory, skin, and food. In particular, it has recently been clarified through overseas exposure study cases that firefighters have a higher rate of exposure via the skin than the respiratory system due to the face mask hood worn during activities at the fire scene [32].

Previous studies have reported that PAHs were exposed to the highest amounts of particulate toxic substances on the body. As a result, the exposure of the neck, face, and wrists was the highest. As such, research results on the exposure of hazardous substances from firefighter fire scenes worldwide are continuously published. This research has been active in the US and North America, but domestic research is still very scarce [32].

In some overseas countries, there was a study that measured the degree of pollution of fire and fire fighting protection suit worn by firefighters during work at a fire scene and the severe of contamination of firefighters during desorption. However, studies on how pollutants attached to fire fighting protection suit simultaneously and secondarily contaminate the surrounding environment are absent and unclear in the academic sense.

In particular, there is no domestic research on the contamination of fire fighting protection suit. Overseas, a recent study on the behavior of firefighters related to the use, washing, and storage of fire protection has been published [26]. Research on domestic fire fighting protection suits was mainly conducted on design performance, thermal fatigue, and burns. In addition, studies on the use, washing, and management of fire protection for firefighters have not yet been conducted. In addition, studies on the vocalization of toxic substances at fire scenes are continuously being carried out, including live fire training center, CFBT (Compartment Fire Behavior Training) facilities. However, there has not been a study on how much toxic substances generated at the fire scene bury in the fire fighting protection suits worn by firefighters and at the same time how much it pollutes the surrounding environment.

2.1.1. *Importance of study*

After firefighters finish fire fighting activities at the fire scene, most of them return to the fire station building while wearing fire fighting protection suits while boarding a fire fighting vehicle, which causes the indoor air quality to deteriorate. In addition, these harmful substances are well known to affect human health.

Firefighters are not properly aware of the hazards and dangers of fire fighting protection suits with combustible substances from the fire scene, so emergency decontamination has not been carried out at the fire scene before returning to the fire station after the firefighting activities have ended. This is a very timely study at the time when firefighters' behavioral changes and consciousness changes are necessary, and systematic management of fire protection is necessary.

2.1.2. *Fire fighting Protective Suit*

Among the firefighters in Korea who are currently dispatched to the fire scene, the driver is required to wear only a fire protection top, and firefighters are required to wear both a fire protection top and bottom. In addition, the number of statutory fire protection suits each firefighter possesses is specified in the Fire Fighting Equipment Act as two sets. In the fire fighting scene, there is a demand that the minimum number of fire fighting protection suits required to perform fire suppression work at the fire scene must be at least three on average.

Fire fighting protection suit is one of personal protective equipment that aims to protect firefighters safely and completely from dangers such as heat, steam and toxic gases. Fire fighting protection suits are worn by firefighters when working at fire extinguishing work at a certain distance from the fire point, and should be able to block heat or vapor to some extent. Therefore, fire protection suits are not only intended to prevent the penetration of water and heat during fire extinguishing, but also to protect firefighters safely and completely, so the material, design, performance standards, etc. There are a wide variety of risk factors in the fire scene, and the protective performance against them is a basic requirement of fire protection suit. The protective performance of fire protection suits can be divided into four broad categories: protection from external heat, protection from mechanical hazardous environments, protection from hazardous chemicals, and protection from heat accumulation inside the fire protection suit. Since various by-products such as ignition by flames, gas explosions, and emission of chemicals during fire suppression may make firefighters dangerous, fire fighting protection suit that prevents such risk factors has the following characteristics.

The material of fire protection suit should be made of flame retardant fiber that does not burn easily, and the generation of static electricity, which causes sparks in gas and vapor fire, should be suppressed. In addition, the generation of toxic gases should be suppressed or not generated when the material of the fire protection suit is burned, and it has the characteristics of heat resistance to withstand the heat and flames generated at the fire scene.

In Korea, firefighting protection suit was enacted as Presidential Decree No. 180 in 1949, and it has been manufactured and distributed in the form of waterproof clothing. In 2001, in the event of a residential fire in Hongje-dong, Seoul, the issue of firefighter safety became an issue as a result of the death of many firefighters. Fire protection suit is a protective clothing that can protect firefighters from flames and heat in the fire fighting scene.

US NFPA code 1851 includes and recommends standards for selection, management and maintenance of protective clothing for fire suppression, selection, inspection, cleaning and decontamination, repair, storage, and disposal.

2.2 Goal of this study

This study is largely divided into questionnaire surveys, experimental studies, and delphi surveys. We would like to present research methods and results by dividing up each study classified according to the purpose of the study.

The purpose of this study is to evaluate the use and management behavior of firefighting suit by firefighters in metropolitan, and to assess the amount and type of contaminated harmful substances buried in fire scenes and turnout gears. The purpose of this study is as follows ;

ⅰ) The first purpose of this study is to assess the association between the use of firefighting protection suit worn by firefighters in metropolitan and the management behavior and public health awareness.

ⅱ) The second objective is to evaluate the amount and type of pollutants primarily generated at fire scenes via single home fire simulation, the most common fire in the country.

ⅲ) The third objective is amount and type of toxic substances on firefighter protection suit worn by firefighters at fire scenes and the amount type of toxic substances that contaminate the surrounding environment are evaluated.

ⅳ) The fourth objectives of this study is to solve the problems derived from the survey and experimental research through delphi survey and determine priorities for policy implementation from the perspective of researches, resources, systems, firefighting suit management, and law and institutions.

2.3 Frame of Study

The overall study framework for carrying out this study is as follows (Figure 2-1).

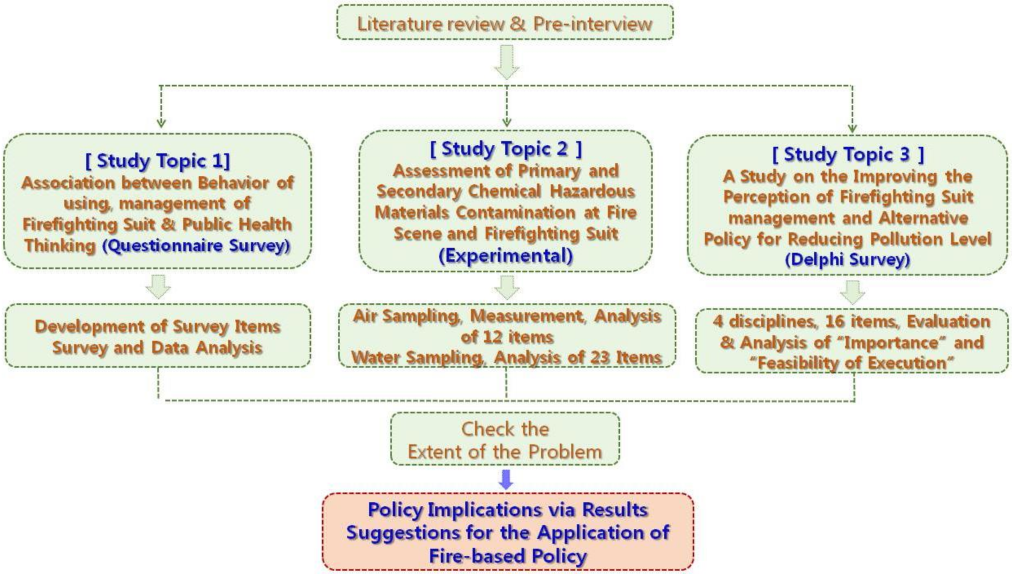


Figure 2-1. Schematic Construction of this Study

Ⅱ-1. Association between Behavior of Using, Washing, Management of Fire Fighting Protection Suit and Public Health Awareness

2.1.1 Study Aims

The purpose of this study is to evaluate the association between behavior of using, washing, management of fire fighting protection suit and public health awareness by firefighters in metropolitan.

2.1.2 Literature Review

We conducted a literature review to find previous studies reporting health-related thinking or recognition for using and management system of firefighters' personnel protective equipment (PPE). The searches were conducted on PubMed and RISS using the following keywords. Searching terms by PICO/PECO (patient population or problem, intervention or exposure, comparison, outcome) are followings ;

- Search terms for PubMed: N= 14 (Firefighter* or Fire-officer*) AND (“Turnout gear” or “Firefighting suit” or “Firefighting clothing” or “Personal Protective Clothing”) AND (use or using or manage or management) AND (awareness or thinking or recognition or health or “public health”) AND (Association)
- Search terms for RISS: title and abstract only: N= 0 (소방관 | 소방공무원) AND (방화복) AND (사용 | 관리) AND (생각 | 인식 | 보건 | 공중보건) AND (연관성)

From the searches restricted to published papers that reported the contamination and chemical pollutant from fire scene, we found 14 papers from PubMed and 0 papers from RISS and DBpia. After excluding studies in languages other than English and Korean, not original studies(e.g. abstract for a conference, oral presentation), and un-related studies, we identified 2 studies relevant to our research. Literature review papers are followings (Table 2-1) ;

Table 2-1. Literature review of studies reporting of firefighting protection suit use & manage-related behavior and health awareness

No	Journal	Author	Year	Nations	Study design	Study subject	Sampling number (participating rate)	Data collection method	Exposure variables	Main outcomes
1	Workplace Health Saf	Macy, G.B. et al	2020	USA	Cross-sectional study	Career FF and Volunteer FF	275 persons (92%)	Questionnaire Survey	Retirement, Cleaning frequency, Storage location of turnout gear	1) proper retirement of turnout gear 2) proper storage of turnout gear 3) proper cleaning of turnout gear All outcomes not statistically significant
2	Advancement of the science	Jooyeon Hwang et al	2019	USA	Qualitative and Quantitative study	Career FF and Volunteer FF	121 persons (53%)	Survey and Interview	Use, storage, cleaning for PPE	1) PPE use, storage, cleaning practices of FF were significant 2) Use, storage, cleaning practices for PPE between career and volunteer firefighter

* Abbreviations : FF; Firefighter, PPE; Personal Protective Equipment

2.1.3 Methods and Materials

2.1.3.1 Study Setting

The Seoul Fire & Disaster Headquarters, located in metropolitan in Korea, is composed of the headquarters, Seoul Fire Academy, the Seoul Emergency Operations Center, Seoul 119 Special Rescue Services, 24 fire stations and 118 safety centers [28]. A total of 7,057 firefighters in Seoul Metropolitan are employed, with 1,392 administrative personnel, 223 emergency dispatcher & communications, 2,248 firefighters, 1,798 fire engine drivers, 487 rescuers, and 909 paramedics [28]. The U.S. is divided into a volunteer firefighter and a career volunteer firefighter, while Korea is composed of career firefighters. Except for the firefighting administration job, the type of work for other jobs is the shift work system.

2.1.3.2 Study Design and Subject

This study design was a cross-sectional study, and web-based survey was conducted using the electronic survey system of Seoul Metropolitan government. As of April 2019, the survey targets were 2,722 shift workers out of 7,057 in-service firefighters in 24 fire departments in Seoul. Of these, a total of 1,097 respondents, and the survey participation rate was 40.3%. The survey method was conducted by the survey subjects using a personal computer or mobile phone through the Seoul electronic survey system (Figure 2-2). At this time, an official letter was sent to the organization where the firefighters and rescuers worked so that the survey subjects could actively participate in the survey (Figure 2-3).

진행중인 설문 | 설문결과

소방 방화복 사용 및 관리 실태조사

본 설문은 2019년도 소방과학연구센터 주관의 「소방 방화복 사용 및 관리 실태조사」를 위한 연구목적으로 구성되어 있습니다. 응답해주시는 결과를 토대로 방화복의 올바른 사용과 관리 등의 정책적 대안을 마련 하고자 본 설문을 시행하게 되었습니다.

전체 설문 응답에는 약 10분 정도가 소요될 예정입니다. 해당조사는 연구자와 직접적인 대면없이 온라인으로만 진행됩니다.
설문 내용에는 개인관련 정보가 일부 포함될 수 있지만, 수집된 개인정보만으로는 개인 식별이 어렵고 추가적으로 개인정보에 임의로 아이디를 부여하는 코드화 작업을 거친 뒤 분석을 실시할 예정이므로 개인정보에 대한 노출은 절대 없음을 알려드립니다.

귀하가 응답하신 내용은 「통계법」 제33조(비밀의 보호) 제①,②항에 따라 철저하게 비밀이 보장되며, 조사 결과는 연구 목적 외에 다른 어떤 용도로도 이용하지 않을 것을 약속드립니다. 바쁘시겠지만 설문에 빠짐없이 협조하여 주시기를 부탁드리오며, 도출된 연구결과가 소방정책에 적용될 수 있도록 노력하겠습니다. 감사합니다.

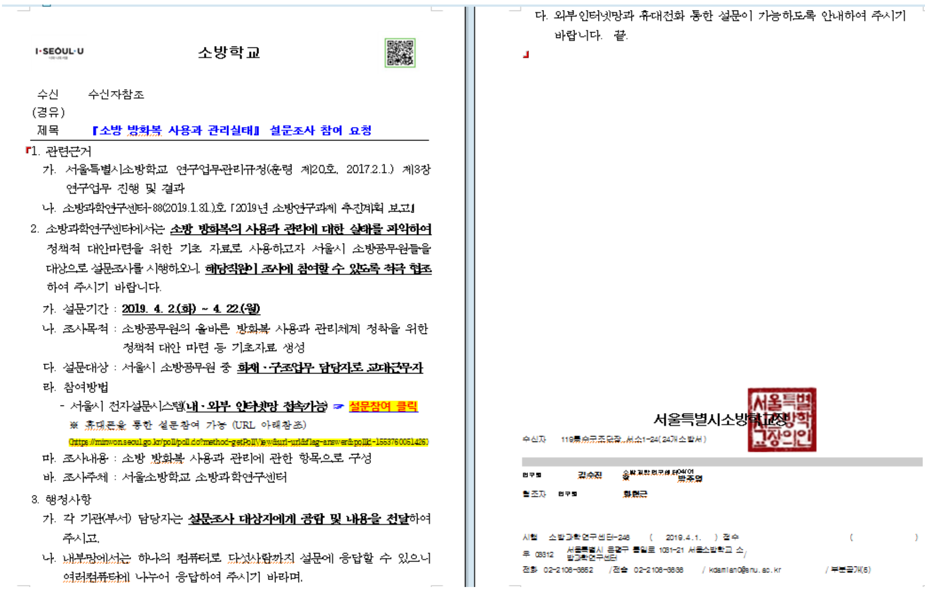
2019년 4월 1일

서울소방학교 소방과학연구센터

*하나의 컴퓨터로 다섯 사람까지 설문에 응답할 수 있으니 여러 PC에 나누어 응답하여 주십시오. 또한, 앞서 설문에 응답하는 분께서 설문을 완료하신 후에 그 다음 분께서 설문에 응답해주시고, 문의사항이 있으시면 아래로 연락주시기 바랍니다.

■ 연구책임자
- 소방과학연구센터 책임연구원 김수진, 02-2106-3652, sjkim865@seoul.go.kr

Figure 2-2. Electronic survey system survey window, in Seoul Metropolitan



I·SEOUL·U

소방학교

수신 수신자참조
(경유)
제목 『소방 방화복 사용과 관리실태』 설문조사 참여 요청

1. 관련근거
가. 서울특별시소방학교 연구업무관리규정(훈령 제20호, 2017.2.1.) 제3장 연구업무 진행 및 결과
나. 소방과학연구센터-88(2019.1.31.)호 「2019년 소방연구과제 추진계획 보고」
2. 소방과학연구센터에서는 **소방 방화복의 사용과 관리에 대한 실태를 파악하여** 정책적 대안마련을 위한 기초 자료로 사용하고자 서울시 소방공무원들을 대상으로 설문조사를 시행하오니, **해당직원이 조사에 참여할 수 있도록 적극 협조**하여 주시기 바랍니다.
가. 설문기간 : **2019. 4. 2.(화) ~ 4. 22.(월)**
나. 조사목적 : 소방공무원의 올바른 방화복 사용과 관리체계 정착을 위한 정책적 대안 마련 등 기초자료 생성
다. 설문대상 : 서울시 소방공무원 중 **화재·구조업무 담당자로 교대근무자**
라. 참여방법
- 서울시 전자설문시스템(**내·외부 인터넷망 접속가능**) ☞ 설문참여 클릭
※ 휴대폰을 통한 설문참여 가능 (URL 아래참조)
(https://minwon.seoul.go.kr/poll/poll.do?method=getPollView&url=url&flag=answer&pollId=1553760051426)
마. 조사내용 : 소방 방화복 사용과 관리에 관한 항목으로 구성
바. 조사주체 : 서울소방학교 소방과학연구센터
3. 행정사항
가. 각 기관(부서) 담당자는 **설문조사 대상자에게 공람 및 내용을 전달**하여 주시고,
나. 내부망에서는 하나의 컴퓨터로 다섯사람까지 설문에 응답할 수 있으니 여러컴퓨터에 나누어 응답하여 주시기 바라며,
다. 외부인터넷망과 휴대전화 통한 설문이 가능하도록 안내하여 주시기 바랍니다. 끝.

서울특별시소방학교장

서울특별시소방학교장인

수신자 119특수구조단장, 서소1-24(24개소방서)

연구원 김수진 소방과학연구센터04/01 박주영
협조자 연구원 황현근

시행 소방과학연구센터-248 (2019.4.1.) 접수 ( )
우 03312 서울소방학교 소방과학연구센터 /
전화 02-2106-3652 /전송 02-2106-3636 / kdamian0@snu.ac.kr / 부분공개(6)

Figure 2-3. Fire fighting protection suit use and management status questionnaire survey participation guide official letter

2.1.3.3 Study Duration

It was classified into 6 domains in order to understand the actual conditions of use, washing, and management of fire protection suit. In addition, survey items were developed through prior research and interviews with experts in the field. The survey period was conducted from April 2, 2019 to April 22, 2019. The purpose and importance of the survey were explained through official texts and social network system (SNS) so that they could participate.

2.1.3.4 Survey variables

The main data variables of the survey is as follows ; 1) Demographic and sociological information (gender, age, marital status, final education, total work year, current task, position, shift work experience), 2) use of fire protection clothing (experience of not wearing fire protection suit at the top and bottom, actual place to change fire protection after firefighting at the fire scene, places where you think it is good to take off fire protection after firefighting activities at the fire scene, experience riding a vehicle after removing fire protection at the fire scene, and boarding a fire engine after separately storing the fire protection worn at the fire scene experience, how to bring the fire protection suit worn at the fire scene to the fire department), 3) Firefighting protection suit washing (general washing method, satisfaction of using a dedicated fire-fighting machine, average number of washing per month, whether or not to wash the inner and outer skin separately, when to wash, whether or not to wash fire-resistant clothing after a fire site activity, type of laundry detergent, awareness of drying method), 4) fire fighting protection suit management (storage method, safety management manual, familiarity with use/storage/washing method, degree of need to introduce advanced overseas management system for fire protection, minimum number of fire protection required when introducing advanced overseas system), 5) awareness of possible occurrence of hazardous substances in disaster scene, firefighters of hazardous materials at disaster scenes information on recognition of potential health effects. Prior to conducting the survey, errors and problems in the questionnaire composition were checked, corrected, and supplemented through a pilot survey, and then applied to this survey.

2.1.3.5 Measurement and Statistical analysis

The distribution of categorical variables is reported as percentages. The continuous variables that were not distributed normally are presented as medians with interquartile ranges. The adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were calculated after adjusting using multivariable logistic regression analysis, including age, level of education, job rank, current job duty variables.

A multiple logistic regression analysis was performed to determine whether there was any association between the using, washing, management of firefighting protection suit and public health related thing, recognition after adjusting for potential confounders and the odds ratio (ORs) and their 95% confidence intervals (CI) were calculated. Potential confounding factors that were considered to be associated with socio-demographic factors were included in the logistic regression model. These factors socio-demographic variables included age, gender, education level, job ranking, job duty, total working year as firefighter. Continuous variables that were not distributed normally were transformed to categorical variables for the logistic regression model.

To obtain the final model, we tested for interactions between exposure variables and potential covariates, assessed confounding factors, and performed precision level tests. The goodness of fit of the multivariable logistic regression model was tested using the Hosmer-Lemeshow (HL) test with chi-square analysis for calibration performance, and c statistics were measured to assess the discrimination performance of the final models. The analysis was conducted using SAS ver. 9.4 (SAS Institute, Cary, NC, USA).

2.1.4 Results

2.1.4.1 Demographic of study participants

A total of 1,097 firefighters in Seoul participated in this survey. As a result of demographic analysis, gender was 1,071 (97.6%) male, 386 (35.2%) aged 50 or older, 830 (75.7%) married, 576 (52.5%) college graduates. As for the number of years of service, 462 people (42.1%) for 20 years or more, 646 people (58.9%) for firefighters by position in charge, 474 people (43.2%) for the Fire captain by position, and 246 for 1-5 years by shift work experience. The most frequent (22.4%) (Table 2-2).

Table 2-2. Demographic characteristics by career firefighters in Metropolitan

Characteristic	**N**	**%**	**P-value**
Gender			
Male	1071	97.6	<.0001
Female	26	2.4	
Age			
20~29	78	7.1	<.0001
30~39	332	30.3	
40~49	301	27.4	
Over 50	386	35.2	
Marriage status			
Singled	237	21.6	<.0001
Married	830	75.7	
Other	30	2.7	
Level of education			
High school	221	20.2	<.0001
Junior college	272	24.8	
University	576	52.5	
Graduate school	28	2.5	
Number of years as a firefighter			
Less than 1	40	3.6	<.0001
1~4	187	17.1	
5~9	181	16.5	
10~14	119	10.9	
15~19	108	9.8	
Over 20	462	42.1	
Mean, Median, Interqurtile range (IQR)	15.6, 16.0, (6, 25)		
Job duty of firefighter			

Characteristic	N	%	P-value
Fire suppression	646	58.9	<.0001
Fire investigator	23	2.1	
Rescuer	181	16.5	
Incident Safety Officier (ISO)	11	1.0	
Fire engine driver	230	20.9	
Emergency communicator at fire scene	5	0.4	
Job rank of firefighter			
Firefighter	183	16.7	<.0001
Senior Fire Fighter	216	19.7	
Fire Engineer	201	18.3	
Fire Lieutenant	474	43.2	
Over Fire Captain	23	2.1	
Number of years with shift work as a firefighter			
Less than 1	60	5.5	<.0001
1~5	246	22.4	
5~9	200	18.2	
10~15	154	14	
15~20	125	11.4	
Over 20	312	28.4	
Total	1,097	100	

2.1.4.2 General characteristics of fire occurrence and fire emergency departure

The average monthly number of fire mitigations that survey respondents dispatched was 5-10 and 10-15, with 305 (27.8%) and 294 (26.8%), respectively. The average monthly number of fire activations with soot, excluding simple food cooking, was 1 to 3 and 3 to 5, with 265 (24.2%) and 259 (23.6%) respectively. The average number of fire activations that washed fire protective clothing after returning fire station from fire scene was 1 to 3 and 3 to 5, respectively, with 442 (40.3%) and 246 (22.4%) fires (Table 2-3).

Table 2-3. General characteristics of fire occurrence & emergency activation in Metropolitan

Characteristic	**N**	**%**	**P-value**
Monthly average number of Fires			
1~5	95	8.7	<.0001
5~10	305	27.8	
10~15	294	26.8	
15~20	169	15.4	
20~25	83	7.6	
Over 25	151	13.7	
Monthly average number of Fires with soot			
Less than 1	50	4.5	<.0001
1~3	265	24.2	
3~5	259	23.6	
5~8	214	19.5	
8~10	118	10.8	
10~15	76	6.9	
Over 15	115	10.5	
Monthly average number of Fires that required cleaning after returning fire station			
Less than 1	164	15.0	<.0001
1~3	442	40.3	
3~5	246	22.4	
5~8	124	11.3	
8~10	45	4.1	
10~15	40	3.6	
Over 15	36	3.3	
Total	1,097	100.0	

2.1.4.3 Characteristics of Using of Firefighting Protection Suit among Firefighters

It is a general characteristic of the use of fire protection clothing worn for personal protection at fire scenes. Out of total 1,097 respondents, 999 cases (9.1%) responded that they had no experience in removing their fire protection tops and bottoms before returning to the fire scene. Among the total respondents, 999 cases

(9.1%) responded that they had no experience of undressing their fire protection jackets and bottoms before returning to the fire scene. 160 cases (35.4%), 154 cases (34.1%) and 69 cases (15.3%) responded that the reason for taking off the fire protection suit before boarding the fire engine was due to the prevention of the inflow of contaminants at the fire scene inside the fire engine, and it was frustrating and smelling (Table 2-4).

As for the places where they actually take off their fire protection after firefighting, 408 people (48.3%) and 351 people (41.6%) responded to the garage after returning fire stations and 351 people (41.6%), respectively, and 77 (9.1%) responded to the fire scene before boarding the fire engine. However, to the question of where they would like to take off their fire protection suit after fire fighting, 503 people (47.0%), 353 (33.0%), and 208 (19.4%) responded to the garage after returning fire stations, the fire scene, and the fire engine at fire stations, respectively. Therefore, it was confirmed that there is a difference in priority between the places where the actual fire protection suits are undressed and the places where it is desirable to take off (Table 2-4).

Only 452 respondents (41.2%) answered that they had experience of taking off the top and bottoms of fire protection at least once before boarding a fire engine after the firefighting activities at the fire scene for the past year or so. In addition, only 165 (15.0%) responded to the experience of taking off and storing the fire protection suit after the firefighting activity at the fire scene was completed and boarding a fire engine. Finally, regarding the method of bringing fire protection after firefighting at the fire scene, 694 (63.3%) and 477 (43.5%) respondents, respectively, in the order of taking off the fire engine and fixing it on a chair and wearing it. 13 (1.2%) and 5 (0.5%) respondents answered that they were brought in a plastic bag or in a collection box (Table 2-4).

Table 2-4. General characteristics of the using of turnout gear

Characteristic	N	%	P-value
The experience of not wearing jumper & pants of fire suits at the fire scene			
Yes	98	8.9	<.0001
No	999	91.1	
Place of turnout gear taking off after cleaning up the fire scene			
Fire scene before riding in a fire engine	77	9.1	<.0001
in a fire engine	351	41.6	
in a fire garage	408	48.3	
in a waiting room	4	0.5	
Other	4	0.5	
Place where turnout gear are ideal to wear			
Fire scene before riding in a fire engine	353	33.0	<.0001
in a fire engine	208	19.4	
in a fire garage	503	47.0	
in a waiting room	4	0.4	
Other	2	0.2	
Experiences in wearing turnout gear before boarding fire engine after fire activities at fire scene			
Yes	452	41.2	<.0001
No	645	58.8	
Experiences in riding fire engine after fire activities at fire scene, storing turnout gear separately			
Yes	165	15.0	<.0001
No	932	85.0	
How to bring turnout gear after fire activities at fire scene			
Come in with one's turnout gear	335	35.7	<.0001
Take it off the fire engine and fix it on the chair	546	58.2	
in airtight container	6	0.6	
in a collection box	4	0.4	

Characteristic	N	%	P-value
Other	48	5.1	
Total	1,097	100.0	

2.1.4.4 Characteristics of Firefighting Protection Suit Washing and Management among Firefighters

This is a general characteristic of firefighters' fire protection suit washing and maintenance. As for the main washing methods for firefighting protection suit, 827 persons (76.1%), 195 persons (18.0%), and 60 persons (5.5%) responded in the order of fire protection suits washing machine, general washing machine, and hand washing, respectively. Satisfaction with cleanliness after washing was mostly 504 people (45.9%). As for the average number of times of washing fire protection suits per month, 747 persons (68.1%) were the most frequent, and 634 persons (57.8%) answered that the inner and outer skins of fire protection suits were always washed separately. 661 (60.3%) responded when fire protection clothes were washed with foreign substances such as soot, and 334 (30.4%) responded that fire protection suits smelled like burnt smell. In the question of whether to wear fire protection suits worn at the fire scene for the past year or so after being washed, the most people answered ″normal″ with 28.7% (315 people). However, there were 289 (26.4%) negative responses who said "No." As for the types of detergents used when washing fire protection suits, 590 (55.0%) and 481 (44.8%) respondents, respectively, of a general neutral detergent and a detergent for fire protection suit. Lastly, 604 (55.1%) responded that they did not know the degree of awareness of how to dry fireproof clothing (Table 2-5).

Table 2-5. General characteristics of the washing of turnout gear

Characteristic	**N**	**%**	**P-value**
Main washing methods of turnout gear			
Turnout gear washing machine	827	76.1	<.0001
Washing machine	195	18.0	
Hand washing	60	5.5	
Others	4	0.4	
Satisfaction with cleanliness after washing			
Very satisfied	49	4.5	<.0001
Satisfied	299	27.3	
Normal	504	45.9	
Not satisfied	190	17.3	
Absolutely not satisfied	55	5.0	
Monthly average number of turnout gear washed			
1~2	747	68.1	<.0001
3~4	244	22.2	
5~6	51	4.7	
Over 7	55	5.0	
Status of separate laundry of turnout gear inside and outside			
Always	634	57.8	<.0001
Often	220	20.1	
Normal	99	9.0	
Not often	96	8.7	
Not at all	48	4.4	
Turnout gear washing point			
After each fire	75	7.0	<.0001
When foreign substances, such as soot are smeared on the turnout gear	661	61.6	
When the turnout gear smells like a burnt back	333	31.0	
Others	4	0.4	

Characteristic	N	%	P-value
Status of wearing after turnout gear used at fire scene			
Always	198	18.1	<.0001
Often	295	26.9	
Normal	315	28.7	
Not often	251	22.9	
Not at all	38	3.5	
Types of laundry detergents for turnout gear			
General neutral detergent	590	55.0	<.0001
Turnout gear exclusive detergent	481	44.8	
Others	2	0.2	
Recognized how to dry turnout gear			
Yes	493	44.9	0.0008
No	604	55.1	
Total	1,097	100	

As for the method of storing fireproof clothing, 587 (54.1%) and 215 (19.8%) responded that they were folded and stored, and some were folded and stored together. The Fire Department has created a safety management manual for fire protection and distributed it to fire departments nationwide. When asked about familiarity with this manual, 623 people (56.8%) answered that they did not know well. In addition, when asked how well they know how to use, store, and wash fireproof clothing, 235 people (21.4%) answered that they did not know well. Only 56 people (5.1%) knew exactly (Table 2-6).

Table 2-6. General characteristics of the management of turnout gear

Characteristic	N	%	P-value
How to store turnout gear			
On the hanger	215	19.8	<.0001

Characteristic	N	%	P-value
Folding	587	54.1	
Hang it on a hanger and fold some of it for storage	283	26.1	
Others	12	1.1	
Recognition of the safety management manual for turnout gear			
Yes	474	43.2	<.0001
No	623	56.8	
Recognition of methods of use, storage, laundry of turnout gear			
Very knowing	56	5.1	<.0001
Knowing	235	21.4	
Normal	571	52.1	
Do not known	215	19.6	
Absolutely not known	20	1.8	
Total	1,097	100	

2.1.4.5 Proper Using, Washing, Management of Turnout Gear by Demographic Factors and Public health related awareness

The effect of the degree of recognition of hazardous substances occurring at the disaster site on the use, washing and management of fire protection clothing was confirmed. The use of fire protection was analyzed by dividing into two areas: the place where fire protection clothes were actually removed after fire fighting activities at the fire scene and the place where fire protection clothes were considered good to take off. The correlation between the degree of awareness of the fire protection clothing drying method was evaluated in the fire suit washing, and the degree of familiarity with the fire protection safety management manual in terms of management (Table 2-7).

In the use of fire protection, when it is recognized that there is a possibility of hazardous substances occurring at a disaster site, and when it is considered that fire protection should be removed from the fire scene, it is 1.92 times (95% confidence interval 1.01-3.68). When it was recognized that there was a possibility of occurrence of hazardous substances at a disaster scene, the actual case of taking off fire protection at the fire scene was 1.24 times higher (95% confidence interval 0.43-3.57). In the case of washing fire fighting protection suits, the case of recognizing the possibility of occurrence of hazardous substances at the disaster scene, and the case of familiarizing the drying method when washing fire fighting protection suits were 1.35 times higher (95% confidence interval 0.81-2.31). In the case of recognizing the possibility of occurrence of hazardous substances in the disaster site, the case of well-familiarity with the safety management manual for fire protection was 1.26 times higher (95% confidence interval 0.74-2.16) (Table 2-7).

In the case of a health accident, it affected the accident about the contamination of fire protection clothing used at the fire site, while it did not affect the behavior about the contamination of fire protection clothing. In addition, it did not affect the behavior of drying fire suits and the recognition of the management manual. It was confirmed that individual health accidents affect certain accidents in certain situations, but do not change behavior.

Table 2-7. Proper Using, Cleaning, Storage of Turnout Gear by Demographic Factors and Public health related awareness

Predictor	Total		Unadjusted			Model 1			Model 2		
	N	%	OR	95% CI		AOR	95% CI		AOR	95% CI	
Outcomes: Proper thinking of take off place of turnout gear	353		1.99	1.04	3.81	1.92	1.01	3.68	1.91	0.83	4.41
Gender											
Male	347	98.3				1.00			1.00		
Female	6	1.7				0.00			0.00		
Age											
20~29	27	7.6				1.00			1.00		
30~39	124	35.1				1.16	0.69	1.95	0.91	0.43	1.96
40~49	101	28.6				0.96	0.57	1.63	0.63	0.24	1.66
Over 50	101	28.6				0.68	0.41	1.14	0.25	0.09	0.73
Job rank of firefighter											
Firefighter	64	18.1							1.00		
Senior Fire Fighter	82	23.2							1.44	0.77	2.70
Fire Engineer	56	15.9							0.80	0.35	1.87
Fire Lieutenant	141	39.9							2.50	1.01	6.23
Over Fire Captain	10	2.8							4.76	1.19	18.97
Job duty of firefighter											
fire suppression	168	47.6							1.00		
fire investigation	11	3.1							2.10	0.71	5.96
rescue	79	22.4							2.01	1.25	3.24
incident safety officier	2	0.6							0.52	0.06	4.41
fire engine driver	93	26.3							1.39	0.91	2.15
Education level of firefighter											
Less than High school	82	23.2							1.00		
College	89	25.2							1.01	0.60	1.71
University	173	49.0							0.88	0.54	1.42
Over Graduate school	9	2.5							0.96	0.31	2.99
Taking off firefighter protention suit at fire scene	66	18.7							0.05	0.02	0.08

(Model 1) Hosmer and Lemeshow Goodness-of-Fit Test, chi-square; 0.02, P-value: 0.99, c-statistic; 0.57

(Model 2) Hosmer and Lemeshow Goodness-of-Fit Test, chi-square; 3.89, P-value:

0.79, c-statistic; 0.75

* OR: Odds ratio, AOR: Adjusted odds ratio, CI: Confidence interval

Table 2-7. Proper Using, Cleaning, Storage of Turnout Gear by Demographic Factors and Public health related awareness (cont.)

Predictor	Total		Unadjusted			Model 1			Model 2		
	N	%	OR	95% CI		AOR	95% CI		AOR	95% CI	
Outcomes: Proper take off place of turnout gear	77		1.14	0.40	3.25	1.24	0.43	3.57	1.19	0.40	3.56
Gender											
Male	77	100.0				1.00			1.00		
Female	0	0.0				0.00			0.00		
Age											
20~29	5	6.5				1.00			1.00		
30~39	12	15.6				0.59	0.20	1.75	0.60	0.13	2.71
40~49	27	35.1				1.53	0.56	4.15	1.45	0.24	8.84
Over 50	33	42.9				1.35	0.50	3.59	2.14	0.30	15.07
Job rank of firefighter											
Firefighter	8	10.4							1.00		
Senior Fire Fighter	8	10.4							0.66	0.16	2.71
Fire Engineer	18	23.4							2.24	0.49	10.29
Fire Lieutenant	42	54.5							0.89	0.16	4.78
Over Fire Captain	1	1.3							0.68	0.04	10.64
Job duty of firefighter											
fire suppression	24	31.2							1.00		
fire investigation	2	2.6							1.56	0.28	8.52
rescue	9	11.7							1.08	0.42	2.75
fire engine driver	42	54.5							4.62	2.44	8.71
Education level of firefighter											
Less than High school	26	33.8							1.00		
College	18	23.4							0.78	0.35	1.74
University	31	40.3							0.65	0.30	1.39
Over Graduate school	2	2.6							0.75	0.11	5.27
Taking off firefighter protection suit at fire scene	2	2.6							23.75	11.67	48.29

(Model 1) Hosmer and Lemeshow Goodness-of-Fit Test, chi-square; 0.53, P-value: 0.97, c-statistic; 0.59

(Model 2) Hosmer and Lemeshow Goodness-of-Fit Test, chi-square; 0.79, P-value: 0.99, c-statistic; 0.89

* OR: Odds ratio, AOR: Adjusted odds ratio, CI: Confidence interval

Table 2-7. Proper Using, Cleaning, Storage of Turnout Gear by Demographic Factors and Public health related awareness (cont.)

Predictor	Total		Unadjusted			Model 1			Model 2		
	N	%	OR	95% CI		AOR	95% CI		AOR	95% CI	
Outcomes: Proper recognition of turnout gear washing	493		1.31	0.78	2.21	1.35	0.81	2.31	1.91	0.81	4.53
Gender											
Male	490	99.4				1.00			1.00		
Female	3	0.6				0.00			0.00		
Age											
20~29	34	6.9				1.00			1.00		
30~39	139	28.2				0.93	0.56	1.52	0.91	0.47	1.77
40~49	125	25.4				0.92	0.56	1.52	0.69	0.29	1.61
Over 50	195	39.6				1.33	0.82	2.17	0.99	0.39	2.51
Job rank of firefighter											
Firefighter	74	15.0							1.00		
Senior Fire Fighter	89	18.1							1.09	0.48	2.47
Fire Engineer	86	17.4							1.87	0.67	5.21
Fire Lieutenant	235	47.7							1.59	0.53	4.74
Over Fire Captain	9	1.8							0.60	0.13	2.70
Job duty of firefighter											
fire suppression	297	60.2							1.00		
fire investigation	5	1.0							0.33	0.11	1.03
Rescue	78	15.8							0.79	0.51	1.22
Incident safety officier	5	1.0							1.28	0.33	4.93
fire engine driver	105	21.3							0.93	0.65	1.33
Emergency communicator	3	0.6							1.98	0.29	13.43
Education level of firefighter											
Less than High school	105	21.3							1.00		
College	126	25.6							1.15	0.85	1.76
University	248	50.3							1.04	0.70	1.53
Over Graduate school	14	2.8							1.46	0.58	3.66
Taking off firefighter protection suit at fire scene	379	76.9							1.34	0.82	2.20

(Model 1) Hosmer and Lemeshow Goodness-of-Fit Test, chi-square; 0.24, P-value:

0.97, c-statistic; 0.55
(Model 2) Hosmer and Lemeshow Goodness-of-Fit Test, chi-square; 12.39, P-value: 0.13, c-statistic; 0.59
* OR: Odds ratio, AOR: Adjusted odds ratio, CI: Confidence interval

Table 2-7. Proper Using, Cleaning, Storage of Turnout Gear by Demographic Factors and Public health related awareness (cont.)

Predictor	Total		Unadjusted			Model 1			Model 2		
	N	%	OR	95% CI		AOR	95% CI		AOR	95% CI	
Outcomes: Proper recognition of turnout gear management SOP	474		1.31	0.78	2.21	1.26	0.74	2.16	1.37	0.75	2.50
Gender											
Male	469	98.9				1.00			1.00		
Female	5	1.1				0.00			0.00		
Age											
20~29	29	6.1				1.00			1.00		
30~39	104	21.9				0.77	0.46	1.28	0.76	0.39	1.49
40~49	127	26.8				1.24	0.74	2.06	1.24	0.52	2.95
Over 50	214	45.1				2.11	1.28	3.49	2.20	0.85	5.66
Job rank of firefighter											
Firefighter	60	12.7							1.00		
Senior Fire Fighter	74	15.6							0.89	0.50	1.56
Fire Engineer	75	15.8							0.77	0.37	1.60
Fire Lieutenant	254	53.6							0.96	0.43	2.15
Over Fire Captain	11	2.3							0.68	0.20	2.36
Job duty of firefighter											
fire suppression	284	59.9							1.00		
fire investigation	8	1.7							0.99	0.37	2.63
Rescue	73	15.4							0.95	0.61	1.47
Incident safety officier	4	0.8							0.83	0.21	3.21
fire engine driver	102	21.5							1.09	0.76	1.57
Emergency communicator	3	0.6							1.42	0.23	8.90
Education level of firefighter											
Less than High school	109	23.0							1.00		
College	125	26.4							1.31	0.84	2.02
University	224	47.3							0.96	0.65	1.42
Over Graduate school	16	3.4							1.52	0.60	3.85
Taking off firefighter protection suit at fire scene	379	80.0							1.01	0.61	1.66

(Model 1) Hosmer and Lemeshow Goodness-of-Fit Test, chi-square; 0.80, P-value: 0.93, c-statistic; 0.61
(Model 2) Hosmer and Lemeshow Goodness-of-Fit Test, chi-square; 2.36, P-value: 0.96, c-statistic; 0.64
* SOP: Standard operation procedure, OR: Odds ratio, AOR: Adjusted odds ratio, CI: Confidence interval

2.1.5 Discussion

This study investigated the epidemiologic characteristics of firefighters' use, washing, and management of firefighters in metropolitan. In addition, based on the results of the research, we investigated the association between the use of fire fighting protection suit, washing, and management behavior according to the presence or absence of a health awareness in which firefighters recognize carcinogens occurring at the disaster scene. This study is the result of a study targeting career firefighters in the Korean system. Firefighters play a role in protecting citizens' safety, such as fire suppression, life search and rescue, and fire investigations at disaster scene. In such a unique and dangerous working environment, firefighters must wear heavy personal protective equipment sets including fire fighting protection suit while working at the fire scene, and perform work while relying on their own safety. As such, it is one of the equipment that protects the lives of firefighters, and it is very important to use and manage them correctly.

Until now, there have been no studies on the use, management, and behavioral relevance of fire fighting protection suit in South Korea. Similar studies consist of two recent studies published in the United States. In both studies, differences between career firefighters and volunteer firefighters were studied due to the characteristics of the United States, and the behavior and execution methods of firefighters' use, washing, storage, and disposal of fire protection were compared and evaluated. At the beginning of this study, there were no similar studies on the use and management behavior of fire protection clothing that were conducted overseas and published [27].

Compared to volunteer firefighters, career firefighters had a significantly smaller number of participants in the study, and the age of the participants was younger, and the number of years of employment as firefighters tended to be higher (Hwang Joo-yeon's thesis). Volunteer firefighters and career firefighters surveyed the rate of personal protective equipment used in the field. Personal protective equipment payment rates for the Career firefighter group are as follows ; 100% for gloves, 95% for turnout gear, helmet, hoods, footwear, 89% for self-contained breathing apparatus (SCBA), eye protection, masks, and 37% for hearing protection. Overall, the volunteer firefighter group's personal protective equipment payment rate was higher than that of the career group. However, the number of career firefighters who participated in this study was very limited, so it would be difficult to generalize this study [26].

In our study, the number of fire fighting protection suits actually owned was 297 (27.1%) for 1 pair, 696 (63.5%) for the second, 98 (8.9%) for the third, and 6 (0.6%) for more than four. The number of fire protection suits stipulated by the Fire Equipment Management Act is two sets for each individual. There were 27.1% of firefighters with quantities that did not meet legal information retention standards. In other words, 27.1% of firefighters are in a situation where they are forced to wear and leave the fire protection clothes that are already dirty and contaminated when a continuous fire outbreak occurs. This would lead to failure to comply with NFPA 1581 code's firefighter health and safety recommendations. In addition, in Korea, there is no strict designation for washing machines for fire fighting protection suit. When asked about the minimum number of fire fighting protection suits required for field activities, 563 (51.3%) for 2nd suits, 484 (44.1%) for 3rd suits, 39 (3.6%) for 4th suits, and 11 (1.0%) for 5th or more. In fact, it is necessary to additionally allocate firefighters who perform fire work with less than two fire fighting protection suits. In addition, in order to operate the system for changing contaminated fire fighting protection suits at the fire scene for the safety and health of firefighters, it is necessary to change through revision of legal information flow rate.

In a previous study, the storage location of fire protection was investigated [26]. This is important in terms of proper management of fire protection clothing. As a result of the study, in the case of career firefighters, 74% were kept in fire station lockers, 21% in private vehicles, and 11% in fire trucks. Volunteer firefighters had 53% in private vehicles, 50% in fire station lockers, and 9% in fire trucks and homes. There was statistical significance in the difference between the two groups' storage locations for fire protection (p=0.027). In our study, there was no result on the storage location of fire protection clothing, but the storage method was investigated. There were 587 people (53.5%) who folded and kept their fireproof clothes, 283 people (25.8%) hung them on a hanger and kept some of them folded together, and 215 people (19.6%) kept them on a hanger ($p <. 0001$).

In the preceding study, as the time point of washing fire protection clothing, career firefighters were analyzed to be 53% after fire fighting, 42% for SOP compliance, and 37% for dirty things [26]. Also, the difference between volunteer groups was not statistically significant. In our study, there was a difference in perception at the time of washing, as 61.6% when stained with soot or other foreign substances, 31.0% when smells such as burnt smell from fire suit, and 7% after every fire suppression activity ($p < .0001$).

In addition, the average number of monthly routine cleaning of career firefighters was less than 6 times a month and 37% after each use, 5% more than 7 times a month, and 11% said they did not [26]. And the difference between volunteer groups was not statistically significant. In our study, the average number of washings per month was 68.1% for 1-2 times, 22.2% for 3-4 times, 5.0% for 7 or more times, and 4.7% for 5-6 times ($p <.0001$).

In our study, the public health awareness related to the occurrence of carcinogens at the disaster scene of firefighters affects the idea of making the right decision to prevent cross-contamination inside the fire fighting vehicle by taking off the firefighting suit before boarding the firefighting vehicle in certain situations where it is necessary to take off the fireproof clothing after a fire activity. However, it was confirmed that there is no statistical significance in the desirable behavior of firefighters taking off their actual fire protection and boarding a fire fighting vehicle. Therefore, there is a need for a device that enables firefighters who are active in various disaster scene and are exposed to hazardous substances to recognize health-related facts and to perform practically desirable actions. In other words, in order to induce actions that promote health for health and safety by firefighters themselves, such as on-scene decontamination of personal protective equipment including contaminated fire fighting protection suit in disaster scene activities, stimulation and action cues are required.

Ⅱ-2. Assessment of Primary and Secondary Contamination of Chemical Pollutants on Turnout Gear at Fire Scenes

2.2.1 Study Aims

The purpose of this study is to evaluate the degree of contamination of primary and secondary chemical substances in residential fire scenes and fire fighting protection suits by measuring types and amounts of chemically hazardous substances

2.2.2 Literature Review

We conducted a literature review to find previous studies reporting the using and management system of firefighters' personnel protective equipment (PPE). The searches were conducted on PubMed and RISS using the following keywords. Searching terms by PICO/PECO (patient population or problem, intervention or exposure, comparison, outcome) are followings ;

- Search terms for PubMed: N= 22 (Firefighter* or Fire-officer*) AND (PPE or “Turnout gear” or “Personal Protective clothing” or “firefighting protective suit”) AND (“Fire Scene” or Fire*) AND (Pollutant* or Contamination*)
- Search terms for RISS: title and abstract only: N= 2 (소방관 ∣ 소방공무원) AND (소방 방화복 ∣ 개인보호장비) AND (화재 ∣ 화재현장) AND (오염물질 ∣ 오염)

From the searches restricted to published papers that reported the contamination and chemical pollutant from fire scene, we found 22 papers from PubMed and 2 papers from RISS and DBpia. After excluding studies in languages other than English and Korean, not original studies(e.g. abstract for a conference, oral presentation), and un-related studies, we identified 6 studies relevant to our research. Literature review papers are followings (Table 2-8) ;

Table 2-8. Literature review of studies reporting of directed or secondary chemical exposures and contaminated firefighters in fire scene

No	Journal	Author	Year	Nations	Study design	Sampling sites	Measurement item	Sampling number	Sampling method	Exposure method at fire scene	Measurement situation	Main outcomes
1	Sci Total Environ	Jennifer LA. Keir et al	2020	Canada	Experimental study	PPE, Skin and Personal clothing surface	PAHs, antimony, cadmium, lead	29 Air sample and 12 washing PPE sample	Air, Wipe	Direct And indirect	Fire suppression, before & after emergency firefighting	1) **Air concentrations** exceeded occupational **exposure limits at 2 fire events for lead, nine for PAHs** 2) After fire suppression, **PAH concentrations** were **significantly higher in skin, PPE(p<0.001) skin clothing, PPE for antimony(p<0.001, 0.01, 0.05 respectively)**, **skin, PPE for lead(p<0.001)** 3) Air concentrations of PAHs and antimony were significantly higher in vehicle bays compared to the office(p<0.05).

No	Journal	Author	Year	Nations	Study design	Sampling sites	Measurement item	Sampling number	Sampling method	Exposure method at fire scene	Measurement situation	Main outcomes
2	Int J Hyg Environ Health	Abrard, S. et al	2019	France	Experimental study	Fire jackets, PPE and tool surface	BaP, PAHs	8 Air sample	Air	Indirect	Single & multiple session of live fire training	1) Single session : **BaP deposit of 113.75 ± 45.003 ㎍/㎡** on exposed **fire jacket** 2) Single session : BaP deposit of **range from 12 to 157 ㎍/㎡** on exposed **PPE , tools** 3) Multiple session : cumulative effect
3	J Occup Environ Hyg	Fent, K. W. et al	2018	USA	Experimental study	PPE, Skin	PAHs, VOCs, HCN	63 exterior surface of turnout jackets & 12 Offgas turnout jackets and trousers sample	Wipe, Offgas	Indirect	Pre-fire, Post-fire, Post-Decon	1) PAH level increase

No	Journal	Author	Year	Nations	Study design	Sampling sites	Measurement item	Sampling number	Sampling method	Exposure method at fire scene	Measurement situation	Main outcomes
4	J Occup Environ Hyg	Alexander, B. M. et al	2016	USA	Experimental study	PPC (glove, hood, coat wristlet)	Methylene chloride, PBDEs	4 hoods, 1 coat, 3 globes	Common: Cut in half, 10cm sqaure Hood: chest edge to chin edge, Coat: hand side to arm side, Glove: wrist edge to finger edge	Indirect	Detectable concentration of at least in PBDE	Expose to PBDE flame retardants at levels much higher than the general public.
5	Environ Sci Technol	Park, J. S. et al	2015	USA	Experimental study	Firefighter blood serum	POPs, PBDEs, PCBs,	101 firefighter questionn	Blood sampling	Indirect	On duty	Lower levels of serum PBDEs were associated with turnout gear cleaning & storage

No	Journal	Author	Year	Nations	Study design	Sampling sites	Measurement item	Sampling number	Sampling method	Exposure method at fire scene	Measurement situation	Main outcomes
						level	OCPs	aire respond And 35 fire stations				practices after fires. 1) Cleaning turnout gear: significantly 30% reduction in BDE-47 & 100, non-significantly reduction in BDE-99 and -153. 2) Cleaning at the response site was associated with elevated BDE-99.
6	J Occup Environ Hyg	Kirk K. M. et al	2015	Australia	Experimental study	PPC & Equipment	PAHs	5	Air, Wipe, Offgas	Direct And indirect	2-story Live fire training,	

* Abbreviations : PPE; Personal Protective Equipment, PPC; Personal Protective Clothing, PAHs; polycyclic aromatic hydrocarbons, BaP; benzo[a]pyrene, VOCs; volatile organic compounds, PBDEs ; polybrominated diphenyl ethers, POPs; persistent organic pollutants, PCBs; polychlorinated biphenyls, OCPs; organo chlorine pesticides,

2.2.3 Methods and Materials

2.2.3.1 Study Setting

The number of fires occurring nationwide in Korea was 40,030 per year, and 284 deaths were reported. Of these, residential fires accounted for the largest share, with 7,543 cases (18.8%) and 122 deaths (43.0%) [33]. According to the classification according to the fire place, as for the place where the fire occurred in Korea, there were 12,002 cases (28.3%) of residential facilities, and 5,895 cases (13.9%) of industrial facilities, 5,067 cases (12.0%), life service 4,361 cases (10.3%), sales and business facilities 2,599 cases (6.1%), and forestry 2,258 cases (52.3%) [33]. Therefore, in this study, residential fire, one of the residential facilities, which is the most common type of fire in Korea, was set as the research environment.

2.2.3.2 Study Design and Subject

This study design is an experimental study. The types and amounts of pollutants were evaluated on the occurrence of chemically hazardous substances occurring at the residential fire scene and on the fire protection suit worn by firefighters and engaged in fire fighting activities. The experiment of fire fighting protection suit was divided into 4 groups. From Group 2 to Group 4, three sets of fire protection suit were allocated for each group. This is to minimize the occurrence of errors in measured values during experiments. Group 1 is newly paid and has never been used, while Group 2 is the fire protection currently being used at the fire scene. Group 3 was exposed to fire once, and Group 4 was exposed to fire twice in succession. For the fire protection suits of Group 3 and Group 4, tops and bottoms were hung on hangers respectively in order to simulate the environment that firefighters wear at the fire scene. In addition, the reason why 4 groups were exposed to fire twice in a row is that firefighters continue to wear fire protection suits without washing them after visiting the actual fire scene.

At this time, chemical hazardous substances generated at the fire scene may accumulate in the fire fighting protection suit and remain in the fire fighting protection suit, but this is to evaluate the risk of how much hazardous substances remain in the fire fighting protection suit. Both groups 3 and 4 were placed in the simulation set, and incomplete combustion was performed primarily.

In order to equalize the experimental conditions for fire fighting protection suit, the same year of manufacture, country of manufacture, size, and fabric composition were selected to remove any bias that may occur in the experimental results (Table 2-9).

Table 2-9. Fire protection suit conditions and quantity by experimental group

	Total	Group 1	Group 2	Group 3	Group 4
Fire suit Condition	-	New payment	in use & washing	1 fire exposure (incompleted fire)	Fire exposure twice in a row (completed fire)
Quantity	10set	1set	3set	3set	3set

2.2.3.3 Experimental Setting

2.2.3.3.1 Measurement environment & Method

This experimental study was conducted by dividing the fire fighting protection suit into 4 groups with a residential fire as a home in a temporary building in the Seoul fire academy. The experiment was conducted from 8 am to 19:00 on Thursday, May 16, 2019. From 8 a.m. to 14 p.m., primary pollutant generation at the fire scene was monitored and air sampled. And from 17 o'clock to 19 o'clock, air sampling for secondary pollution was performed in the laboratory of the Seoul Fire School in order to reproduce the degree of the secondary contamination of the pollutants in the fire fighting protection suits. An experimental set similar to a studio was created by composing the internal environment of a temporary building with furniture and items used in real houses. The scale of the experimental simulation set was 3.3 x 3.3 m^3. The interior of the private house was set to reflect the characteristics of the bedroom and living room, and the interior of the temporary building, which is the environment for conducting the experiment, was also constructed very similar to the environment of the actual house. The schematic diagram of the interior projected vertically from the ceiling is as follows (Figure 2-4).

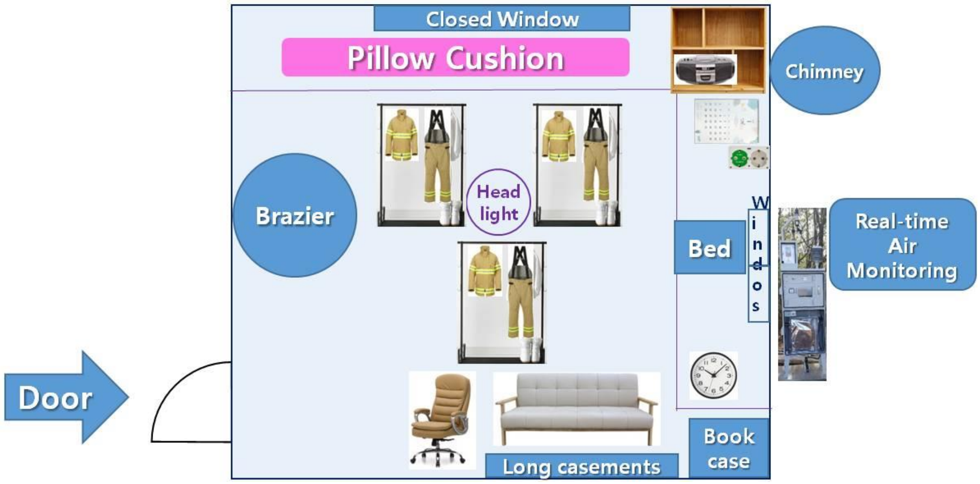


Figure 2-4. Schematic diagram of the inside of the test scene for measuring the contamination of hazardous substances at the fire scene and fire protection clothing

The fire fighting protection suit was reproduced similarly to the situation where a firefighter actually extinguishes a fire inside the fire scene by dividing the top and bottom by dividing the top and bottom on the stand-type hanger inside the simulation set. In addition, when the inside of a temporary building is actually ignited to simulate a residential fire, not only the internal structure but also the fire fighting protection suit can all be burned down. Therefore, a certain amount of the combustion products that actually existed in the experimental area were put into the furnace inside the temporary building, and the door was closed after burning. Incomplete combustion and complete combustion were carried out by controlling the amount of oxygen injected through the window of the temporary building to create fire conditions.

2.2.3.3.2 Preparation and test conditions of fire fighting suit used in the experiment

The fire fighting protection suit used in the experiment was a newly-paid fire fighting protection suit that had never been used in one of ten. Nine sets of fire fighting protection suits were used by actual firefighters from 3 fire departments In addition, in order to eliminate the possibility of floating matter and residual detergent in the fire suit before the experiment, 9 sets were additionally washed once for 45 minutes each with water without any detergent in a washing machine dedicated to fire protection suits in the Seoul Fire Academy (Figure 2-5).

Washing before fire fighting suit experiment	Fire fighting protection suit drying

Figure 2-5. Washing treatment before testing fire fighting protection suits

In this experimental study, an experiment was conducted in a simulated environment in a temporary building with a residential fire as an environment in the Seoul Fire Academy. The fire fighting protection suit used in this experiment is a size 6 made in Sancheong, Philippines in 2013. Generally, if the year of manufacture and country of manufacture are the same, the material of the fire fighting protection suit is considered to be the same. The outer, lining, and felt fabrics used in this experiment were 100% aramid fibers. The moisture-permeable waterproof cloth is composed of 100% aramid fiber and PTFE film. In addition, the reflective tape is treated with 100% aramid fiber and a reflective recoating with a width of 75 mm (Table 2-10).

Table 2-10. Demographics of Simulated Firefighter Protection Suit by Group Distribution

	Group 1	Group 2	Group 3	Group 4
Classification of firefighter protection suit	New payment	Washed firefighter protection suit in use	1 fire exposure	Fire exposure twice in a row
Year of manufacture	2013	2013	2013	2013
Manufacturer	Philippines Sancheong	Philippines Sancheong	Philippines Sancheong	Philippines Sancheong
Size	No. 6	No. 6	No. 6	No. 6
Fire exposure	None	None	Incomplete combustion	Complete combustion
Firefighter protection suit tops and bottoms (Common to groups 1~4)				

2.2.3.4 Experimental Setting & Data collection

2.2.3.4.1 Pollutant Exposure protocol

The experimental protocol for measuring exposure to hazardous substances in fire scenes and fire fighting protection suits is as follows ;

1. Inside the temporary building, 6 sets of fire fighting protection suits for groups 3 and 4 are hung on internal hangers to create an environment similar to that in which firefighters extinguish fires indoors.

2. Various combustibles that can come out of the house were put in the oven inside the temporary building and burned for 60 minutes. At this time, the type and amount of the combustible material included polyurethane, sofa, plastic bag, plastic plastic bottle, paper, newspaper, blanket, etc., and were evenly cut into a certain size. The amount of oxygen flowing into the interior was controlled through an open window, a structure of a temporary building. In addition, the situation of cleaning up after the fire was reproduced in the same way. Simultaneously with the start of fire combustion, the collection of harmful substances generated inside the temporary building was started, and the measurement sample medium was replaced once 30 minutes after the start of the measurement.

3. After 60 minutes from the start of the measurement in the situation of an incomplete combustion fire, two firefighters wore full-body personal protective equipment and entered the temporary building to bring out the fire fighting

protection suits included in the 3rd group. Hazardous substances at the fire scene are characterized by volatile characteristics, so 3 sets of fire fighting protection suits were put in a container, sealed, and returned.

4. Twenty minutes after the measurement of exposure to hazardous substances at the fire scene was completed, the second complete combustion, flame fire test was started. In addition, the hydrogen cyanide filter was replaced 20 minutes after the start of the measurement.

5. 60 minutes after the start of the flame fire measurement, two firefighters entered the test measurement site again. The fire protection suit included in Group 4 was put in a container, sealed, and brought back.

6. In order to measure the secondary exposure of hazardous substances at the fire scene, air sample was collected in a laboratory on the 11th floor of the Seoul Fire Academy, all fire fighting protection suits for groups 1 to 4 were put in containers and sealed. At this time, the air sample was collected by creating conditions that could cause secondary pollution (cross-contamination) of harmful substances buried in the fire fighting protection suit.

2.2.3.4.2 Primary and Secondary Combustion in the fire scene

The primary combustion was performed in the state of incomplete combustion (smoke fire) and the generation of harmful substances was measured, and the secondary combustion was measured in the state of complete combustion (flame fire). In order to resemble the situation in which firefighters engage in fire fighting activities at the fire scene, fire fighting suits were exposed, including the time to clear up after the fire. At this time, oxygen injection into the interior was controlled while observing the color of the smoke erupting out using an open window to control the oxygen conditions in which smoke and flame fires may occur. Metals, formaldehyde, and mixed organic compounds were each measured for about 1 hour, and hydrogen cyanide was measured twice for about 15 minutes.

Considering that the experiment was in a combustion situation, all pumps required for measurement were placed outside the experiment container and the sample collection media were placed inside about 5cm indoors using a Tygon tube through a window (Figure 2-6). Considering that most of the smoke discharged through the window in the combustion situation is discharged from the upper part of the window, the upper upper part of the place where the sample was placed was closed with a paper box and the experiment was conducted (Figure 2-6). However, as the combustion continued, it could not withstand the heat and was removed, and the shape of the Media 3 piece cassette was also partially melted. The air collected in this experiment was a situation in which air could not be collected under the worst conditions of the scene, and the measured data of this experiment result implied the possibility of underestimation. Therefore, when analyzing and evaluating the measurement results at the fire scene, it can be inferred that the measured concentration at the fire scene may be higher than the results of this experiment.

	
Air sampling of harmful substances inside and outside temporary buildings	Check whether the measuring equipment is operating normally

Figure 2-6. Air sampling of hazardous substances in the fire scene

2.2.3.4.3 Air environment measurement and method for cross-contamination of fire protection suit

Metals, formaldehyde, and mixed organic compounds were measured twice for each group for about 1 hour to 1 hour 30 minutes, and hydrogen cyanide for about 15 minutes. Fire fighting protection suits exposed to each fire combustion process were sealed in a vacuum polyvinyl bag inside the laboratory after combustion was completed, and then transferred to the laboratory. At this time, in order to minimize the dropout of harmful substances in the fire fighting protection suit, two of the study participants entered the simulation set while wearing a self-contained breathing apparatus (SCBA), face mask, fire fighting protection suit, and gloves, and moved the experimental fire fighting protection suit to a bag inside. Each group's fire fighting protection suit was put in a total of 3 vacuum bags, and each group had 3 samples (Figure 2-7).

For sample collection, the air inside three vacuum bags for each group is measured at the same time, and the total measurement time for each group is about 1 hour to 1 hour 30 minutes for metals, formaldehyde, and mixed organic compounds, and about 15 minutes for hydrogen cyanide. In order to know the degree of cross-contamination caused by fire fighting protection suit, the degree of secondary air contamination caused by harmful substances remaining in the fire fighting protection suit was measured. During the measurement, the pump was placed outside the vacuum bag, and only the media for sample collection was connected to the Tygon tube and measured by putting it into the vacuum plastic bag. At this time, two measures were taken to minimize air loss inside the vacuum bag. For one thing, the external air inlet cap of the vacuum bag was opened and closed several times during the experiment. The other was sealed as much as possible except for the inlet of the Tygon tube.

Two firefighters put on personal protective equipment such as fire fighting protection suit and self-contained breathing apparatus (SCBA), and then extinguished them inside the experiment space (Figure 2-7). In order to reproduce the situation to find out the diffusion concentration of secondary contamination in the indoor air during the fire scene activity, the vacuum bag was shaken within the range that did not affect the experiment.

Fire exposure and storage of fire protection at the fire scene in experimental temporary buildings	Air sampling of secondary exposure to atmosphere

Figure 2-7. Collection of fire protection suits in the fire scene and indirect exposure air collection

Burning of the upper part of a experimental temporary building, burning of interior and exterior windows, and structural transformation

Figure 2-8. Burning inside and outside of temporary buildings at the fire site and structural deformation

However, due to the limitation of the limited internal space of the vacuum plastic bag, it was judged that there was a limitation in accurately evaluating metals only by measuring air sampling, so an additional water analysis was performed by washing the fire fighting protection suit.

2.2.3.5 Variables and Outcome measurement

2.2.3.5.1 Air component measurement and analysis

2.2.3.5.1.1 Formaldehyde

Formaldehyde measurement and analysis were performed according to the method of KOSHA GUIDE A-56-2015. Sample collection is about 0.3 L/min by connecting a silica gel tube coated with 2,4-DNPH (300/150 mg, 226-119, SKC Inc., PA, USA) to a low flow pump (GSA, SG350, Germany). The sample collection pump was calibrated before and after sample collection using a flow rate compensator (KEMIC, KMF 20, KOREA). In order to analyze the sampled silica gel, 2 ml of Acetonitrile was injected, and left to stand for 30 minutes or more while shaking occasionally. The samples were analyzed by detaching the front layer (300 mg) and the rear layer (150 mg), respectively. The desorbed sample was analyzed by high-performance liquid chromatography (HPLC) (WATERS, Alliance2695, USA), and specific analysis conditions are as follows (Table 2-11).

Table 2-11. Analytical conditions for Formaldehyde using HPLC

Variables	**Conditions**
Carrier	DI water/Acetonitrile (55:45)
Flow	1.0 ml/min
Injector volume	10 ㎕
Column	SUPELCOSIL LC-18-DB (15cm x 4.6 ㎜ x 5 ㎛)
Detector	UV Detector 360nm

The quality of the sample was confirmed by the retention time by injecting a standard material of Formaldehyde-2, 4-DNPH 1,000 μg/ml (CHEM SERVICE, S12011W4). For quantification, a calibration curve was prepared by diluting the substance step by step and obtained from it. The standard solution was prepared at an amount similar to that of the expected field sample. Desorption efficiency was carried out at the same time when the sample was analyzed (Figure 3-7), and a certain amount of formaldehyde 1000 μg/ml methanol (Accu standard, M-554 -06) was injected using a microsyringe. Three samples were prepared at three concentration levels (0.1 to 2 times the exposure standard), left for one day, and analyzed as a blank sample to calculate the desorption efficiency (Figure 3-7). In addition, the detection limit of formaldehyde was 0.011 μg/ml.

$$\text{Desorption efficiency} = \frac{\text{Detection amount}}{\text{Injection volume}} = \frac{\text{Analytical Volume}}{\text{Theoretical quantity}}$$

Figure 2-9. Desorption efficiency calculation formula

2.2.3.5.1.2 Heavy metal (Pb, Cd, Cu, Fe, Mn, Al, Ni, Co, As)

Measurement and analysis of heavy metals (Pb/Cd/Cu/Fe/Mn/Al/Ni/Co/As) are performed by referring to the method of NIOSH (US National Institute for Occupational Health and Safety; NIOSH) 7300 (ELEMENTS by ICP). The sample was collected by attaching a 37 mm cellulose ester membrane filter to a 3 piece cassette and connecting it to a high flow pump (CASELLA, TUFF I.S. ENGLAND) to about 2 L/min. In addition, the sample collection pump performed flow rate correction using a flow rate corrector (DEFENDER, 510-M, USA) before and after sample collection. The MCE filter from which the sample was collected is injected with 5 ml of HNO_3 as a pretreatment solution, incubated on a hot plate, mass-up with 10 ml of distilled water, and then with an inductively coupled plasma emission spectrometer (ICP/OES) (AVIO500DV, PerkinElmer, USA) Analyzed. The quality of the sample was confirmed by selecting the wavelength of the heavy metal to be analyzed, such as Pb and Cd, in the device. For quantification, a standard solution was prepared by diluting each substance step by step, and a calibration curve was prepared from this.

Table 2-12. Limits of detection (LOD) of heavy metals

Material	LOD (mg/*l*)
Pb	0.0048
Cd	0.0007
Cu	0.0026
Fe	0.0020
Mn	0.0024
Al	0.0036
Ni	0.0021
Co	0.0012
As	0.0161

2.2.3.5.1.3 Hydrogen Cyanide

Hydrogen cyanide was measured according to the NIOSH Manual of Analytical Method (NMAM) of the National Institute for Occupational Safety and Health (NIOSH). According to the NIOSH 6010 method, the sample collection medium was a Solid Sorbent Tube (Soda lime, 600 mg/200 mg, SKC Inc., USA). In addition, air was collected at 0.2 L/min using a high volume pump (EX-350, GSA, Germany). Analysis was carried out using a spectrophotometer (UV-Vis Spectrophotometer, UV mini-1240, Shimazu, Japan). The detection limit of Hydrogen Cyanide was 0.007 μg/ml.

2.2.3.5.1.4 Mixed organic compounds

For measurement and analysis of mixed organic compounds, the method of KOSHA GUIDE A-72-2018 was applied mutatis mutandis. Samples were collected by connecting an activated carbon pipe (100/50 mg, 226-01, SKC Inc., PA, USA) to a low flow pump (GSA, SG350, Germany) to obtain about 0.3 L/min. The sample collection pump was calibrated before and after sample collection using a flow rate compensator (KEMIC, KMF 20, KOREA). In order to analyze the sampled activated carbon tube, 1 ml of CS_2 was injected and left for 30 minutes or longer for analysis. The sample was analyzed by detaching the front layer (100 mg) and the rear layer (50 mg), respectively. The detached sample was analyzed by gas chromatography (GC/FID) (7890b, Agilent, USA). The method of measuring and analyzing air sampling components is as follows (Table 2-13).

Table 2-13. Air sampling component measurement and analysis method

No	Collecting ingredients	LOD	Media	Analysis equipment	Analysis method
1	Formaldehyde	μg/ml	Silica gel tube coated with 2,4-DNPH	HPLC	KOSHA GUIDE A-56-2015
2	Hydrogen cyanide	μg/ml	Solid adsorption tube (Soda Lime)	UV	NIOSH 6010
3	Mixed organic solvent	-	Solid adsorption tube (Coconut shell charcoal)	GC	KOSHA GUIDE A-72-2018 A-73-2018, etc
4	Lead and its inorganic compounds	μg/L	MCE	ICP-OES	KOSHA GUIDE A-2-2018
5	Cadmium and its compounds	μg/L	MCE	ICP-OES	KOSHA GUIDE A-14-2018
6	Copper (Hume)	μg/L	MCE	ICP-OES	KOSHA GUIDE A-1-2015
7	Iron oxide dust and fumes	μg/L	MCE	ICP-OES	KOSHA GUIDE A-18-2015
8	Manganese and its inorganic compounds	μg/L	MCE	ICP-OES	KOSHA GUIDE A-10-2015
9	Aluminum and its compounds	μg/L	MCE	ICP-OES	KOSHA GUIDE A-10-2015
10	Nickel (insoluble inorganic compound)	μg/L	MCE	ICP-OES	KOSHA GUIDE A-3-2018
11	Cobalt and its inorganic compounds	μg/L	MCE	ICP-OES	KOSHA GUIDE

No	Collecting ingredients	LOD	Media	Analysis equipment	Analysis method
12	Arsenic and Soluble Compounds	μg/L	MCE	ICP-OES	A-15-2018 KOSHA GUIDE A-51-2018

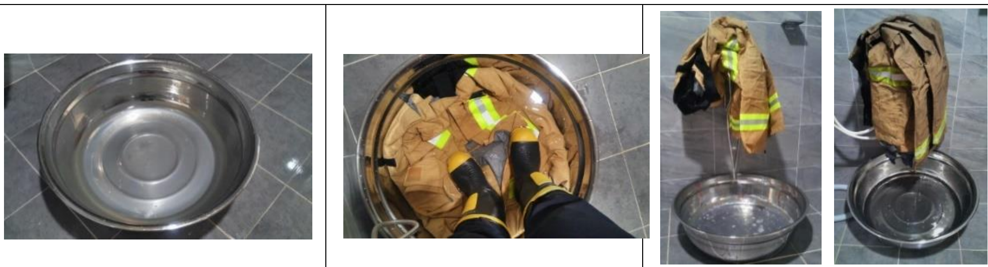
* LOD : Limit of detection, HPLC : High-performance liquid chromatography, KOSHA : Korea occupational safety & health agency, UV : Ultraviolet, GC : Gas chromatography, ICP-OES : coupled plasma optical emission spectrometry, MCE : Mixed Cellulose Esters Membrane Filter, NIOSH : National Institute for Occupational Safety and Health

2.2.3.5.2 Extraction and analysis of laundry components

2.2.3.5.2.1 How to extract laundry components for fire protection

In order to find out the degree of secondary cross-contamination due to contaminants of fire fighting protection suit, laundry water analysis was performed on 10 fire fighting protection suits classified into groups 1 to 4. At this time, the laundry method was extracted through manual washing. Liquid fire protection suit was extracted from 8:30 pm on May 19 (Sun) to 3:40 am on May 20 (Mon) at a designated location within the Seoul Fire Academy. At this time, the extracted laundry water was not subjected to separate chemical treatment and proceeded to the analysis step. The manual washing method and procedure are as follows :

The washing machine was not used, and tap water was received in a circular aluminum basin by a manual method, and the top and bottom of the fire fighting protection suit were completely immersed in water. At this time, all 10 sets of fire fighting protection suit were folded in the same way, placed in the same location in the basin, and received the same amount of water. Laundry water was extracted in a way that one person stepped on it and washed, and water was extracted by stepping on it for 20 minutes per fire fighting protection suit. In addition, in the intermediate step between washing and washing, the aluminum basin was cleaned and rinsed several times to remove harmful substances from the circular basin. This is to eliminate the factors affecting the next laundry composition and increase the accuracy of water analysis. When water is extracted using a washing machine, it may be affected by scale and residual detergent remaining in the existing washing machine. Therefore, the manual method was selected for laundry water extraction. In this study, the order of washing and extracting the laundry was performed in the order of group 1 to 4 groups (Figure 2-10).



The process of extracting laundry by group after stepping on the fire fighting protection suit after receiving water in the basin for 20 minutes

Figure 2-10. Firefighting protection suit laundry water extraction process

In general, there is a possibility that the extracted material may be deteriorated by sunlight. Taking this into consideration, the extracted fire protection clothes were put in a brown container that stores sensitive substances, and the container lid was sealed with a film used in the laboratory to block it from the external environment. Furthermore, in order to minimize the error value in the analysis step, 3 bottles were extracted for all 4 groups of fire fighting protection suit except for the basic material used for analysis.

Sealing and sorting of washing water for fire fighting protection suit classified into 4 groups

Figure 2-11. Sealing and labeling of washing water extract for fire fighting protection suit

Stored washing water extracted from fire fighting protection suit in a designated container.

Figure 2-12. Measures to store washing water for fire-fighting suits and move them to analysis institutions

2.2.3.5.2.2 Firfighting protectione suit water component analysis method

Washing water for fire fighting protection suit was analyzed according to the water pollution process test standard. For the analysis of heavy metals such as arsenic, ES 04400.3c metals inductively coupled plasma atomic emission spectroscopy was applied mutatis mutandis. The analysis method for volatile organic compounds was based on ES 04602.1b. Vinyl chloride, acrylonitrile, and bromoform were based on ES 04603.2b, a headspace/gas chromatograph mass spectrometry method. Finally, for volatile organic compounds-headspace/gas, chromatographic mass spectrometry was applied mutatis mutandis.

Analysis of heavy metals is performed by adding nitric acid (5 mL) to the sample (45 mL) according to the micro acid decomposition method (ES 04150. 1b), a pretreatment method suggested in the water pollution process test method, and decomposing organic substances and interfering substances by irradiating microwaves under high temperature and high pressure conditions. Analysis was performed using ICP-OES (Agilent-5100). For the analysis of volatile organic compounds, QP-2010Ultra from Shimadzu (Japan) was used.

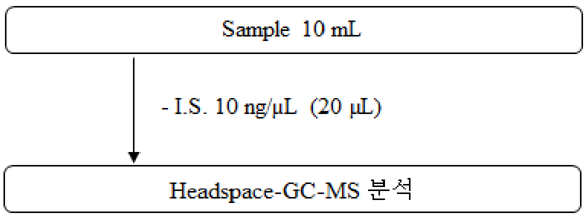
For analysis, take 10 mL of a sample and transfer it to a 40 mL vial, add 20 μL of an internal standard solution (10 ng/μL) to the sample.), and analyzed by GC-MS after pretreatment of the headspace by sealing with a silicone stopper coated with the material. Table 3-9 shows the analysis method of laundry water of fire fighting protection suit. As a result of the analysis, the coefficient of determination (R^2) value was more than 0.999 for heavy metals and 0.99 or more for volatile organic compounds.

The quantification range of volatile organic compounds was set to 1-100 μg/L, and the method detection limit (MDL) of volatile organic compounds was quantified by adding a standard substance at a concentration level of 10 μg/L per item. As a result, all of them were measured to be less than 5 μg/L, and all of them were in line with the goal of performing their quality control.

Table 2-14. Heavy metal ICP-OES analysis conditions

Type	Condition
RF power	1.2 KW
Plasma flow	15.0 L/min
Auxiliary flow	1.50 L/min
Nebulizer flow	0.75 L/min
Pump rate	15 rpm

* ICP-OES : inductively coupled plasma optical emission spectrometry



* GC/MS : Gas chromatography/mass spectrometry

Figure 2-13. Volatile Organic Compound Analysis Method

Table 2-15. GC/MS analysis conditions for volatile organic compounds

GC	Condition
Capillary Column	Rtx-624 (60 m x 0.32 mm x 1.8 um)
Oven Temp.	40 ℃ (7 min), 5 ℃/min to 140 ℃ (5 min), 25 ℃/min to 240 ℃ (3 min)
Carrier gas	He, 1.45 mL/min
Intel Temp.	250 ℃
Injection mode	Split (Split ratio: 20)
MS	**Condition**
Ionization	EI mode (electron ionization)
Measuring	SIM mode
Ion source Temp.	200 ℃
Interface Temp.	260 ℃
Solvent cut time	3.5 min
Detector Voltage	0.3 kV

* GC : Gas chromatography, MS : Mass spectrometry,

Table 2-16. Washing water extraction agent and analysis method of fire fighting protection suit

No	Agent	LOD (mg/L)	Analysis method
1	As	0.05	ES 04406.3a Arsenic-inductively coupled plasma-atomic emission spectroscopy
2	Ba	0.003	ES 04405.2a Barium-inductively coupled plasma-atomic emission spectroscopy
3	Cd	0.004	ES 04413.3a Cadmium-Inductively Coupled Plasma-Atomic Emission Spectroscopy
4	Cr	0.007	ES 04414.3a Chromium-inductively coupled plasma-atomic emission spectroscopy
5	Cu	0.006	ES 04401.3a Copper-inductively coupled plasma-atomic emission spectroscopy
6	Ni	0.015	ES 04403.3a Nickel-inductively coupled plasma-atomic emission spectroscopy
7	Pb	0.04	ES 04402.3a Lead-inductively coupled plasma-atomic emission spectroscopy
8	Sb	0.02	ES 04410.1a Antimony-inductively coupled plasma-atomic emission spectroscopy
9	Se	0.03	ES 04407.2a Selenium-Inductively Coupled Plasma-Mass Spectrometry
10	Zn	0.002	ES 04409.3a Zinc-Inductively Coupled Plasma-Atomic Spectroscopy
11	Vinyl Chloride, VC	0.005	ES 04602.1b Vinyl chloride, acrylonitrile, bromoform-headspace/gas chromatography-mass spectrometry
12	1.1-Dichloroethylene	0.005	ES 04603.2b Volatile Organic Compounds-Headspace/Gas Chromatography-Mass Spectrometry
13	Dichloromethan	0.005	ES 04603.2b Volatile Organic Compounds-Headspace/Gas Chromatography-Mass Spectrometry
14	Aacrylonitrile	0.005	ES 04602.1b Vinyl chloride, acrylonitrile, bromoform-headspace/gas chromatography-mass spectrometry
15	Chloroform	0.005	ES 04603.2b Volatile Organic Compounds-Headspace/Gas Chromatography-Mass Spectrometry
16	1.1-trichloroethane	0.005	ES 04603.2b Volatile Organic Compounds-Headspace/Gas Chromatography-Mass Spectrometry
17	Tetrachloromethane	0.005	ES 04603.2b Volatile Organic Compounds-Headspace/Gas Chromatography-Mass Spectrometry
18	1.2-Ethylene_dichloride	0.005	ES 04603.2b Volatile Organic Compounds-Headspace/Gas Chromatography-Mass Spectrometry

No	Agent	LOD (mg/L)	Analysis method
19	Trichloroethylene , (TCE)	0.005	ES 04603.2b Volatile Organic Compounds-Headspace/Gas Chromatography-Mass Spectrometry
20	Perchloroethylene , (PCE)	0.005	ES 04603.2b Volatile Organic Compounds-Headspace/Gas Chromatography-Mass Spectrometry
21	Styrene	0.006	ES 04610.1 Styrene-Headspace, Gas Chromatography-Mass Spectrometry
22	Bromoform	0.005	ES 04602.1b Vinyl chloride, acrylonitrile, Bromoform-Headspace/Gas Chromatography-Mass Spectrometry
23	Naphthalene	0.003	ES 04607.1 Naphthalene-Headspace/Gas Chromatography-Mass Spectrometry
24	Di-(2-Ethylhexyl)phthalate (DEHP)	0.0025	ES 04501.3b Diethylhexylphthalate-gas chromatography-mass spectrometry

* LOD : Limit of detection

In this experiment, we extracted the following data ;

We collected following variables ;

1. 12 agents of primary indoor air generated at fire scenes : formaldehyde, hydrogen cyanide, lead and their inorganic compounds, cadmium and their compounds, copper (fume), iron oxide dust and fumes, manganese and their inorganic compounds, aluminum and their compounds (fume), nickel (insoluble inorganic compounds), cobalt and its inorganic compounds, arsenic and soluble compounds, mixed organic solvents

2. 12 agents of secondary generated indoor air by pollutants on each group of fire fighting protection suits used at the fire scene

3. Laundry water heavy metal 24 items of fire fighting protection suit

2.2.4 Result

2.2.4.1 Analysis result of occurrence of chemically hazardous substances at fire scene

2.2.4.1.1 Results of the occurrence of chemical hazardous substances at the fire scene and fire protection

As a result of air sampling analysis for a total of 12 agents pollutant, the hazardous substances detected at the fire scene were formaldehyde, hydrogen cyanide, lead and its inorganic compounds, aluminum and its compounds (fume). In addition, as hazardous substances detected as secondary contamination of fire fighting protection suit, hydrogen cyanide, lead and inorganic compounds thereof, cadmium and compounds thereof, aluminum and compounds thereof (fume), and nickel (insoluble inorganic compounds) were confirmed.

Formaldehyde is a Class 1 carcinogen by International Agency for Research on Cancer (IARC) and a substance having the characteristics of germ cell mutagenicity. In this experiment, both the primary and secondary fire scenes were detected. In particular, the level exceeding the exposure standard was measured at the secondary fire scene, and the value was 2.65 times higher in flame combustion than in incomplete combustion. However, it was not detected in any group in the fire fighting protection suit.

Hydrogen cyanide is a substance characterized by skin toxicity and was detected in both primary and secondary fire scenes. Although the measured value did not exceed the exposure limit, hydrogen cyanide is labeled with ″C″ as a criterion that should not be exposed even briefly during one day of work, and has a characteristic that causes acute toxicity. Therefore, when personal protective equipment is detached from the fire scene and exposed to the skin, there is a risk of causing acute toxicity through the skin, which has a risk of cumulative toxicity. In particular, hydrogen cyanide was sampled in the air during the secondary contamination of fire fighting protection suit and did not exceed the exposure standard, but there is a risk of cumulative toxicity, so it is necessary to take care not to contaminate the skin when the fire fighting protection suit is detached from the fire scene withdrawal stage. Therefore, when the skin is contaminated, the skin should be washed immediately. Furthermore, as hydrogen cyanide is detected in the fire fighting protection suit of Group 1, it is recommended to wear it after washing if a fire fighting protection suit is newly provided.

Lead and its inorganic compounds were detected in both the primary and secondary fire scenes as a class 1B carcinogen and a reproductive toxicity class 1A material. In the flame combustion fire scene, it was 4.49 times higher than incomplete combustion fire scene. In addition, lead and its inorganic compounds were detected in group 2 of fire fighting protection suits in use and group 4 of fire fighting protection suits exposed to fire twice.

Cadmium and its compounds are substances that have the characteristics of class 1 carcinogen by IARC, germ cell mutagenicity, reproductive toxicity, and respiration (a particulate matter that can enter the alveoli and affect health). It was not detected at the fire scene. However, in group 4, which was exposed to fire twice, it was detected at 1/100 of the exposure standard.

Iron oxide dust and fumes are substances whose toxicity to humans is not well known. In our study, it was detected at a level of 14/10,000 of the exposure standard in the group 3 of fire fighting protection suits that were exposed to fire once.

Aluminum and its compounds (fumes) were detected at both the primary and secondary fire scenes, and 23.8 times higher than incomplete combustion at the completed flame combustion fire scene. In addition, except for group 1, all groups from 2 to 4 groups of fire fighting protection suit were detected, which was 20 times higher in group 4 than group 3.

Nickel, an insoluble inorganic compound was confirmed to be detected only in newly issued fire fighting protection suit, which is a class 1 carcinogen by IARC. However, the amount of nickel detected was 5/10,000 of the exposure standard. In addition, copper (fume), manganese and their inorganic compounds, cobalt and their inorganic compounds, arsenic and soluble compounds and mixed organic solvents were not detected in the fire scene twice. In addition, it was not detected in the fire fighting protection suits of all groups that were secondarily exposed (Table 2-17).

Table 2-17. Outcomes of primary & secondary contamination of chemically hazardous substances at fire scenes & fire fighting protection suit

No	Type of Pollutants	CAS. *	Human toxicity*	Unit *	Exposure standard *	Exposure classification*	Primary fire (Incompleted combustion)	Secondary fire (Flame combustion)	Group1	Group2	Group3	Group 4
							Value	Value	Value	Value	Value	Value
1	Formaldehyde (HCHO)	[50-00-0]	IARC 1A, Carcinogenicity Germ cell mutagenicity 2	ppm	0.3	TWA†	0.1447	**0.3831**	N.D	N.D	N.D	N.D
2	Hydrogen cyanide (HCN)	[74-90-8]	Skin	ppm	C4.7	Ceiling‡	**1.2181**	0.3976	**0.2923**	0.1615	0.1389	0.1541
3	Hydrogen cyanide (HCN)	[74-90-8]	Skin	ppm	C4.7	Ceiling‡	0.2355	0.3653	**0.1483**	0.0986	0.2602	0.2109
4	Lead and its inorganic compounds	[7439-92-1]	IARC 1B Carcinogenicity Reproductive toxicity 1A	mg/㎥	0.05	TWA	0.0037	0.0166	N.D	0.0002	N.D	0.0012
5	Cadmium and its compounds	[7440-43-9]	IARC 1A Germ cell mutagenicity 2, Reproductive toxicity 2, respiration	mg/㎥	0.01	TWA	N.D	N.D	N.D	N.D	N.D	0.0001
6	Copper (humme)	[7440-50-8]	-	mg/㎥	0.1	TWA	N.D	N.D	N.D	N.D	N.D	N.D

No	Type of Pollutants	CAS. *	Human toxicity*	Unit *	Exposure standard *	Exposure classification*	Primary fire (Incompleted combustion)	Secondary fire (Flame combustion)	Group1	Group2	Group3	Group 4
							Value	Value	Value	Value	Value	Value
7	Iron oxide dust and fumes	[1309-37-1]	-	mg/㎥	5	TWA	N.D	N.D	N.D	N.D	0.0007	N.D
8	Manganese and its inorganic compounds	[7439-96-5]	-	mg/㎥	1	TWA	N.D	N.D	N.D	N.D	N.D	N.D
9	Aluminum and its compounds (fume)	[7429-90-5]	-	mg/㎥	5	TWA	0.0005	0.0119	N.D	0.0001	0.0001	0.002
10	Nickel (insoluble inorganic compound)	[7440-02-0]	IARC 1A	mg/㎥	0.2	TWA	N.D	N.D	0.0001	N.D	N.D	N.D
11	Cobalt and its inorganic compounds	[7440-48-4]	IARC 2	mg/㎥	0.02	TWA	N.D	N.D	N.D	N.D	N.D	N.D
12	Arsenic and Soluble Compounds	[7440-38-2]	IARC 1A	mg/㎥	0.01	TWA	N.D	N.D	N.D	N.D	N.D	N.D
13	Mixed organic solvent		-	mg/㎥	1	TWA	N.D	N.D	N.D	N.D	N.D	N.D

* Notification of exposure standards for chemical substances and physical agents (Ministry of Employment and Labor Notification No. 2008-26)

†″Time-weighted average exposure standard (TWA)″ refers to the value obtained by multiplying the measurement value of harmful factors by the occurrence time and dividing it by 8 hours based on 8 hours of work per day.

‡″Maximum exposure standard (C)″ refers to a standard that a worker should not be exposed to even for a short period of time during one working day, and marked with ″C″ in front of the exposure standard.

* N.D : None detection, IARC : International agency for research on cancer, CAS : Chemical abstracts service, TWA : Time weighted average

2.2.4.2. Result of detecting & analyzing hazardous substances in fire protection suits

In order to further analyze the degree of heavy metal contamination of fire fighting protection suits exposed to the fire scene, fire fighting protection suit laundry water analysis was performed. Of the total 24 analysis agents, 8 agents were contaminants detected in the laundry water of fire fighting protection suit.

Barium (Ba) was detected in all 4 groups of fire fighting protection suit, and the largest amount was detected in 3 groups. Copper (Cu) was detected in all 4 groups of fire fighting protection suit, and the largest amount was detected in 3 groups. Nickel (Ni) was detected in the 2-4 groups of fire fighting protection suit, and the largest amount was detected in the 3 group. Antimony (Sb) was detected in 3-4 groups of fire fighting protection suit, and the largest amount was detected in 3 groups. Zinc (Zn) was identified as a heavy metal detected in all four groups of fire fighting protection suits. Acrylonitrile was detected in groups 3 to 4 of fire fighting protection suits, and a larger amount was detected in group 4 than in group 3. This is a result of a clear dose-response relationship between exposure and outcome.

Naphthalene was detected in groups 3 to 4 of fire fighting protection suits, and a larger amount was detected in the incomplete combustion fire exposure in group 3 than in group 4. Diethylhexylphthalate (DEHP) was detected in all groups of fire fighting protection suits, and the largest amount was detected in 3 groups

(Table 2-18). The laundry water of fire fighting protection suits exposed to the fire scene is classified as wastewater in accordance with the Water Environment Conservation Act.

As a result of the analysis of the laundry water of fire fighting protection suits, which was carried out for the survey on the contamination of this fire fighting protection suits, it was confirmed that four agents exceeded the standards for application of wastewater discharge facilities for specific water quality hazardous substances. The four agents that fall under the application criteria for wastewater discharge facilities were identified as copper (Cu), antimony (Sb), acrylonitrile, and Diethylhexylphthalate (DEHP). (Table 2-18).

As a result, it can be inferred that the fire fighting protection suit, which is the personal protective equipment of firefighters at the fire scene, can affect not only human body and air pollution but also water pollution. In addition, it can be confirmed that fire fighting protection suit used in the fire scene can cause serious secondary cross-contamination.

Table 2-18. Outcomes of laundry water analysis on fire fighting protection suit by group distribution

No	Type of Pollutant (unit: mg/L)	IARC Grade	G1	G 2-1	G 2-2	G 2-3	G2 LOD	G 3-1	G 3-2	G 3-3	G3 LOD	G 4-1	G 4-2	G 4-3	G4 LOD	Default water	Stainlessed basin water
1	Arsenic (As)		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	0.026
2	**Barium (Ba)**		**0.019**	0.018	0.059	0.062	**0.046**	0.049	0.090	0.094	**0.078**	0.108	0.019	0.019	**0.049**	0.121	0.019
3	Cadmium (Cd)		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D
4	Chrome (Cr)		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	0.762
5	**Copper (Cu)**		**0.032**	0.030	0.128	0.091	**0.083**	0.132	0.320	0.339	**0.264**	0.219	N.D	N.D	**LOD**	0.033	N.D
6	Nickel (Ni)		N.D	N.D	0.024	0.028	**LOD**	0.024	0.086	0.133	**0.081**	0.066	N.D	N.D	**LOD**	0.031	0.018
7	Lead (Pb)		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D
8	Antimony (Sb)		N.D	N.D	N.D	N.D	-	N.D	0.087	0.096	**LOD**	0.052	N.D	N.D	**LOD**	0.037	0.026
9	Selenium (Se)		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D
10	**Zinc (Zn)**		**0.063**	0.060	0.851	0.723	**0.545**	0.586	2.419	3.010	**2.005**	2.758	0.061	0.052	**0.957**	0.482	0.003
11	Vinyl chloride		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D

No	Type of Pollutant (unit: mg/L)	IARC Grade	G1	G 2-1	G 2-2	G 2-3	G2 LOD	G 3-1	G 3-2	G 3-3	G3 LOD	G 4-1	G 4-2	G 4-3	G4 LOD	Default water	Stainlessed basin water
12	Dichloroethylene-**1.1**		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D
13	Dichloromethane (CH_2Cl_2)		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D
14	Acrylronitrile		N.D	N.D	N.D	N.D	-	0.052	0.054	0.066	**0.057**	0.124	0.13	0.105	**0.120**	N.D	N.D
15	Chloroform ($CHCl_3$)		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	0.014	0.008
16	Trichloroethene-1.1		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D
17	Carbon tetrachloride (CCl_4)		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D
18	1,2-Dichloroethene	3	N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D
19	TCE		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D
20	PCE		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D
21	Styrene		N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D

No	Type of Pollutant (unit: mg/L)	IARC Grade	G1	G 2-1	G 2-2	G 2-3	G2 LOD	G 3-1	G 3-2	G 3-3	G3 LOD	G 4-1	G 4-2	G 4-3	G4 LOD	Default water	Stainlesed basin water
22	Bromoform	3	N.D	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D	N.D	-	N.D	N.D
23	Naphthalene		N.D	N.D	N.D	N.D	-	0.028	0.031	0.022	**0.081**	0.007	0.007	0.006	**0.007**	N.D	N.D
24	DEHP	2B	**0.024**	0.029	0.014	0.011	**0.018**	0.033	0.022	0.034	**0.029**	0.012	N.D	0.010	**LOD**	N.D	0.003

* Abbreviation : G; Group, LOD; Limit of Detection, N.D; None detection, TCE; Trichloroethylene, PCE; Perchloroethylene, DEHP; diethylhexylphthalate

Table 2-19. Criteria for the application of wastewater discharge facilities for specific water toxic substances and the maximum concentration of laundry water for firefighting protection suit

No	Items	Reference concentration (A) (mg/L)	Firefighting suit laundry measure concentration (B) (mg/L)	B/A (Ratio)	Other
1	Cu	0.1	0.339	3.4 times	Group 3-3
2	Sb	0.02	0.096	4.8 times	Group 3-3
3	Acrylronitrile	0.005	0.13	26.0 times	Group 4-2
4	Di-(2-Ethylhexyl)phthalate (DEHP)	0.008	0.033	4.1 times	Group 3-1

* Standards in Article 35-2 of the Enforcement Regulations of the Water Environment Conservation Act

Table 2-20. QA/QC result of laundry water (fire fighting protection suit) quality analysis

No	Item	LOD (mg/L)	MDL (mg/L)	Accuracy, %	Precision, CV
1	Arsenic (As)	0.05	0.007	98.6	0.3
2	Barium (Ba)	0.003	0.002	105.5	0.2
3	Cadmium (Cd)	0.004	0.001	96.7	0.3
4	Chrome (Cr)	0.007	0.002	99.7	0.1
5	Copper (Cu)	0.006	0.001	98.2	0.4
6	Nickel (Ni)	0.015	0.003	98.5	0.0
7	Lead (Pb)	0.04	0.008	95.9	0.1
8	Antimony (Sb)	0.02	0.010	105.6	0.4
9	Selenium (Se)	0.03	0.005	96.5	0.6
10	Zinc (Zn)	0.002	0.001	98.1	0.8
11	Vinyl chloride	0.005	0.003	89.6	9.7
12	1,1-Dichloroethene	0.005	0.003	89.7	8.9
13	Dichloromethane	0.005	0.005	91.8	8.2
14	Acrylonitrile	0.005	0.005	108.4	9.0
15	Chloroform	0.005	0.002	92.4	4.5
16	Carbon tetrachloride	0.005	0.004	94.5	7.0
17	Benzene	0.005	0.002	90.3	4.7
18	1,2-Dichloroethane	0.005	0.003	99.9	4.1
19	Trichloroethene	0.005	0.001	92.5	5.0
20	Tetrachloroethylene	0.005	0.002	95.8	5.9
21	Styrene	0.005	0.0005	100.0	3.0

No	Item	LOD (mg/L)	MDL (mg/L)	Accuracy, %	Precision, CV
22	Bromoform	0.005	0.002	102.8	4.4
23	Naphthalene	0.003	0.0007	100.0	5.0
24	Di-(2-Ethylhexyl)phthalate	0.0025	0.0003	111.1	0.23

* LOD : Limit of detection, MDL : Method detection limit, QA : Quality assurance, QC : Quality control, CV : Coefficient of variation

As a result of the analysis, the coefficient of determination (R^2) value was 0.999 or higher for heavy metals and 0.99 or higher for volatile organic compounds. The quantification range of volatile organic compounds was set to 1-100 μg/L, and the method detection limit (MDL) of volatile organic compounds was quantified by adding a standard substance at a concentration level of 10 μg/L per item. As a result, all of them were measured to be less than 5 μg/L, and all of them were in line with the goal of performing their own quality control. The QA/QC results for each analysis item are shown in Table 2-20.

2.2.5 Discussion

2.2.5.1 Characteristics of primary contamination of hazardous substances occurring at the residential fire scene

In our study, formaldehyde with a value exceeding the exposure limit was detected at the flame combustion scene, where complete combustion occurred, among chemical hazardous substances occurring at the residential fire scene. However, it was not detected in fire fighting protection suit.

Hydrogen cyanide causing acute skin toxicity was found in both incomplete and complete combustion fire scene [34]. In addition, it was also detected in air samples collected from fire fighting protection suit, which could be secondary contaminated. Therefore, in order not to expose the skin to toxic substances in the fire scene, equipment such as the necessity of wearing fire fighting protection suit and training such as the risk of a fire scene is required. Furthermore, it was confirmed that firefighters need to take measures such as emergency gross decontamination and taking off their fire fighting protection suits before boarding the fire fighting vehicle at the stage of withdrawal from the fire scene to prevent contamination inside the fire fighting vehicle and the fire station building.

2.2.5.2 Characteristics of cross-contamination of fire fighting protection suits of hazardous substances occurring at residential fire scenes

As a result of the analysis by collecting air sample in the secondary contamination situation where hazardous substances were embedded in the fire fighting protection suit, hydrogen cyanide and nickel were detected in the newly assigned fire suit. However, it was confirmed that the risk level was not exceeded based on the single exposure. Hydrogen cyanide was detected in all experimental groups, and heavy metals such as lead, iron oxide, aluminum and cadmium were also detected.

In the experimental environment exposed to fire twice in a row, acrylonitrile toxic substances showed positive tendency for a dose-response relationship. This means that there is a risk of increasing toxicity that may affect the human body because the amount of contamination continues to accumulate when the fire fighting protection suit is continuously re-worn without washing after fire suppression, overhaul, investigation activities. In addition, naphthalene, class 1 carcinogen by IARC, was highly detected in fire fighting protection suit exposed to incomplete combustion fires [35].

The laundry water of fire fighting protection suit that has been exposed to the fire scene is classified as wastewater in accordance with the Water Environment Conservation Act. In our study, as a result of analyzing fire fighting protection suit laundry water to investigate the contamination of fire fighting protection suits, it was confirmed that four agents exceeded the standards for application of specific water-hazardous substances wastewater discharge facilities, so that the fire fighting protection suit contamination at the fire scene was serious. Here we can consider two situations. First, contamination of fire fighting protection suit by toxic substances at the fire scene can be very serious. In this case, it is necessary to install wastewater discharge facilities at every fire station. Second, after performing emergency gross decontamination at the fire scene, as a result of additional analysis of the laundry water of fire fighting protection suit, the concentration may not exceed the level prescribed by the Water Environment Conservation Act. In this case, it is necessary for firefighters to perform emergency gross decontamination at the fire scene before withdrawal the fire scene. Therefore, a follow-up study is needed to confirm this possible situation.

Through the results of this study, we were able to estimate the types and amounts of hazardous substances that can occur in a residential fire. Based on the results of this study, it is possible to establish a database (DB) on the types and amounts of hazardous substances that generally occur at residential fire sites. In addition, if there is information on the number of years worked and the number of dispatches of firefighters, it will be possible to calculate the cumulative exposure of hazardous substances exposed at the residential fire scene. These data can be used as scientific evidence to prove whether a firefighter has a disease related to work when a disease occurs. In addition, it will be able to provide a strong scientific evidence for implementing firefighting policies for emergency gross decontamination on-scene for fire fighting protection suits with cross-contamination at the fire scene. Finally, the results of this study can be actively used when promoting the safe use of firefighters' fire fighting protection suit and health-related policies.

Ⅱ-3. A Study on Delphi for Improving the Perception of Firefighting Suit Management and Alternative Policy for Reducing Contamination Level

2.3.1 Study Aims

The purpose of this study was conducted to solve problems related to fire protection suit and determine prioritize policies derived from surveys and experimental studies as Delphi expert survey.

2.3.2 Method and Materials

2.3.2.1 Importance of Delphi Study

According to the survey results, it was confirmed that firefighters lacked health awareness about the use, washing, and management of fire protection. In addition, in the results of this experimental study, it was confirmed that various chemical hazardous substances generated at the fire scene contaminate the surrounding environment as well as the pollutants that are secondarily buried in the fire fighting protection suit. In order to improve these problems, after the fire fighting activities at the fire scene were completed, an expert survey was conducted through in-depth interviews to prepare systematic management and operation such as decontamination of fire fighting protection suits and to derive items to be improved within limited resources.

2.3.2.2 Study Design and Subject

The design of this study is a cross-sectional study. A Delphi expert survey was conducted to solve problems related to fire protection and prioritize policies derived from surveys and experimental studies. This survey targets 7 experts with research experience in fire protection, such as firefighting, safety, and policy, and expertise in the relevant business, and is conducted in one interview and two sessions from October 10 to October 21, 2019. Delphi investigation through revised investigation was performed (Table 2-21).

Table 2-21. Demographic of delphi survey on turnout gear

No	Stage	Duration	Method
1	Pilot survey	2019. 10. 10. ~ 10. 14. (5days)	Face to face interview
2	1 round survey	2019. 10. 16. ~ 10. 18. (3days)	Electrical mail
3	2 round survey	2019. 10. 22. ~ 10. 25. (4days)	Electrical mail

3.3.2.3 Measurement and Statistical analysis

The content of the survey was a ″importance″ evaluation of firefighters' use of fire fighting protection suit and management system improvement plans, a "practicability" evaluation, and priorities were selected by comprehensively considering "importance" and "practicability".

The importance and practicability index of the policy were given from 1 to 5, and 5 points means that the importance and practicability are very high. On the other hand, a score of 1 means that it is not at all important and the practicability is very low. Based on this, the importance and practicability index were derived. The weights for each score (5, 4, 3, 2, 1 point) were assigned 100, 75, 50, 25, and 0. The formula for calculating the importance and practicability index is as follows (Figure 2-14, Figure 2-15).

$$\textbf{Importance index } (\boldsymbol{I}) = \frac{I_{5\text{ points}} \times 100 + I_{4\text{ points}} \times 75 + I_{3\text{ points}} \times 50 + I_{2\text{ points}} \times 25 + I_{1\text{ points}} \times 0}{I\text{ total}}$$

Figure 2-14. How to calculate the importance index

Here, the importance index ($0 \leqq$ I index $\leqq 100$), which is the I index, is as follows ;

I_5 points : Respondents with 5 points of importance

I_4 points: Respondents with 4 points of importance

I_3 points: Respondents with 3 points of importance

I_2 points: Respondents with 2 points of importance

I_1 points: Respondents with 1 points of importance

I_{total} : Total number of respondents

$$\textbf{Practicability index(P)} = \frac{P_{5\ \text{points}} \times 100 + P_{4\ \text{points}} \times 75 + P_{3\ \text{points}} \times 50 + P_{2\ \text{points}} \times 25 + P_{1\ \text{points}} \times 0}{P\ \text{total}}$$

Figure 2-15. How to calculate the practicability index

Here, the practicability index ($0 \leqq P\ \text{index} \leqq 100$), which is the P index, is as follows;

P_5 points : Respondents with 5 points of practicability

P_4 points : Respondents with 4 points of practicability

P_3 points : Respondents with 3 points of practicability

P_2 points : Respondents with 2 points of practicability

P_1 points : Respondents with 1 points of practicability

P_{total} : Total number of respondents

The 16-item improvement proposals distributed to 7 experts by arranging the matters derived through interviews with firefighters and experts with extensive field experience are divided into 4 areas.

First is the organization, manpower, and budget fields that correspond to resources.

The second is the improvement of the field safety system.

The third is about the quantity, use, operation, and laundry-related work of fire fighting

Finally, it is law and institution (Table 2-22). In order to solve the problems derived from the survey and experimental research, a policy proposal for each field was derived.

Table 2-22. Expert Delphi survey items for personal health and safety of firefighters at fire scenes

Items of assessment
▣ Organization, Manpower, Budget field
1. Hiring professional personnel to improve the management system of personal protective equipment such as firefighters' fire suits
2. Training internal experts for firefighters and introducing and operating a system for firefighters to improve the management system of personal protective equipment such as firefighters' firefighting suits
3. Organize and systematically operate a pool of experts in the field of personal protective equipment such as firefighters' fire protection
4. Reinforcement of professional personnel for systematic operation and improvement of personal protective equipment management system such as firefighters' fire suits
5. Improving the firefighting personal protective equipment management system and securing a budget for systematic operation
▣ Improvement of management system for personal protective equipment such as turnout gear
6. In the disaster scene standard operation procedure (SOP 108, 200, 201), as a user at the stage of the disaster scene (fire, etc.) return procedure, the duty to remove contamination of personal protective equipment during firefighting activities is specified (command team leader or scene safety inspector)
7. Disaster scene (fire, etc.) First decontamination of personal protective equipment at the scene due to the health impact of pollutants Addition of SOP (or manual) and training for fire suppression and rescue personnel
8. Development of training courses for improving the management system of personal protective equipment such as firefighters' fire suits and systematic operation
9. Conduct education on the risk of health effects of pollutants in the disaster scene (fire, etc.)
10. Distinguish non-contaminated areas and contaminated areas in the fire department, and propose a flow map for the movement of firefighters such as changing fire suits, decontamination, showering, washing personal protective equipment, and washing
11. Firefighting equipment organization (tentative name) established
▣ Specific items such as number, use, wash of turnout gear
12. Revision to increase the basic amount of fire protection clothing

Items of assessment
13. Revision of the safety and management manual for personal protective equipment including special fire protection
▣ Law, regulation, program
14. Revision of the Law on Health and Welfare of Firefighting Officials reflecting the specificity of firefighters' work
15. Revision of standard operational procedures for disaster scenes (SOP 108, 200, 201)
16. Revision or enactment of ordinances for installing administrative organizations in Seoul to open firefighting equipment organization

2.3.3 Results

2.3.3.1 Delpi survey

2.3.3.1.1 Demographic findings of participants in expert surveys

A total of 7 respondents to the Delphi survey were male, 6 (57.1%) and female (42.9%), and the average age was 41.6 years (standard deviation 9.8 years). By occupation, there were 3 university professors and 4 firefighters, and the average experience was 11.1 years (standard deviation 6.4 years).

2.3.3.1.2 Priority sum of importance and practicability

Each priority was evaluated by selecting 5 out of the 16 items presented and writing numbers in the 1st to 5th priority. The sum of priorities for each item is calculated by assigning the result collected in this way from 1st priority 5 to 5th priority 1 point.

The sum of the priorities of practicability was calculated by collecting the results of a total of 7 people. The item with the highest score in the sum of' importance' priority is '7. First-line decontamination training for personal protective equipment at the scene level was conducted according to the health effects of pollutants at the disaster scene′, and was evaluated with 15 points. The item with the second highest score was '9. It scored 14 points for 'education on the risk of health impacts of pollutants at disaster scenes'. The item with the third highest score was '8. It was the development of a curriculum for systematic application of the management system for personal protective equipment such as fire fighting protection suits for firefighters, and it was 13 points. The item with the fourth highest score is '5. It was 12 points for securing fire fighting budget, and the next highest item was '11. Firefighting equipment organization (tentative name) newly established′, ′14. Amendment of the Law of the Fire Service Public Health and Welfare Act reflecting the specificity of the firefighting service It was evaluated in the order of fostering internal experts for firefighters and introducing and operating an expert system (Table 2-23).

Table 2-23. Delphi findings on sum of importance priority

Evaluation scale / Evaluation item	Priority result					Sum of importance priority
	1st priority	2nd priority	3rd priority	4th priority	5th priority	
▣ **Organization, manpower, Budget field**						
1. Hiring professional	0	0	0	1 time	0	2

Evaluation scale / Evaluation item	Priority result					Sum of importance priority
	1st priority	2nd priority	3rd priority	4th priority	5th priority	
personnel to improve the management system of personal protective equipment such as firefighters' fire suits						
2. Training internal experts for firefighters and introducing and operating a system for firefighters to improve the management system of personal protective equipment such as firefighters' firefighting suits	0	1 time	0	1 time	0	6
3. Organize and systematically operate a pool of experts in the field of personal protective equipment such as firefighters' fire protection	0	0	0	0	1 time	1
4. Reinforcement of professional personnel for systematic operation and improvement of personal protective equipment management system such as firefighters' fire suits	0	0	0	0	0	0
5. Improving the firefighting personal protective equipment management system and securing a budget for systematic operation	2 times	0	0	1 time	0	**12**
▣ Improvement of management system for personal protective equipment such as turnout gear						
6. In the disaster scene standard operation	0	0	0	0	0	0

Evaluation scale / Evaluation item	Priority result					Sum of importance priority
	1st priority	2nd priority	3rd priority	4th priority	5th priority	
procedure (SOP 108, 200, 201), as a user at the stage of the disaster scene (fire, etc.) return procedure, the duty to remove contamination of personal protective equipment during firefighting activities is specified (command team leader or site safety inspector)						
7. Disaster scene (fire, etc.) First decontamination of personal protective equipment at the scene due to the health impact of pollutants Addition of SOP (or manual) and training for fire suppression and rescue personnel	1 time	2 times	0	1 time	0	**15**
8. Development of training courses for improving the management system of personal protective equipment such as firefighters' fire suits and systematic operation	1 time	1 time	1 time	0	1 time	**13**
9. Conduct education on the risk of health effects of pollutants in the disaster scene (fire, etc.)	2 times	0	1 time	0	1 time	**14**
10. Distinguish non-contaminated areas and contaminated areas in the fire department, and propose a flow map for the movement of firefighters such as	0	0	1 time	0	0	3

Evaluation scale / Evaluation item	Priority result					Sum of importance priority
	1st priority	2nd priority	3rd priority	4th priority	5th priority	
changing fire suits, decontamination, showering, washing personal protective equipment, and washing						
11. Firefighting equipment organization (tentative name) established	0	1 time	1 time	0	1 time	**8**
▣ Specific items such as number, use, wash of turnout gear						
12. Revision to increase the basic amount of fire protection clothing	0	0	0	1 time	0	2
13. Revision of the safety and management manual for personal protective equipment including special fire protection	0	0	0	0	Twice	2
▣ Law, regulation, program						
14. Revision of the Law on Health and Welfare of Firefighting Officials reflecting the specificity of firefighters' work	0	1 time	0	1 time	0	6
15. Revision of standard operational procedures for disaster scenes (SOP 108, 200, 201)	0	0	0	0	0	0
16. Revision or enactment of ordinances for installing administrative organizations in Seoul to open firefighting equipment organization	0	0	2 times	0	0	6

The item with the highest score in the sum of' practicability' priority is '7. First-line decontamination training for personal protective equipment at the scene level was conducted according to the health effects of pollutants at the disaster scene′ and was evaluated with 29 points. The item with the second highest score was '8. It was the development of a curriculum for systematic application of the personal protective equipment management system, such as fire protection for firefighters′, and was evaluated with 24 points. The next highest items are '9. Conduct education on the risk of health effects of pollutants at disaster scenes', '13. Revision of the Safety and Management Manual for Fire Fighting Clothing′, ′5. Securing the fire fighting budget', '10. Establishing flow map standards for firefighters' movements, such as changing fire clothing, decontamination, showering, washing personal protective equipment, washing, etc. through classification of non-contaminated and contaminated areas in the fire department's office′. '14. Amendment of the Law of the Fire Service Public Health and Welfare Act reflecting the specificity of firefighting work′, '2. Training internal experts for firefighters and introducing and operating an expert system′, '11. Firefighting equipment window (tentative name) was newly established′ (Table 2-24).

Table 2-24. Delphi findings on sum of practicability priorities

Evaluation scale / Evaluation item	Priority result					Sum of practicability priorities
	1st priority	2nd priority	3rd priority	4th priority	5th priority	
▣ **Organization, manpower, Budget field**						
1. Hiring professional personnel to improve the	0	0	0	0	0	0

Evaluation scale / Evaluation item	Priority result					Sum of practicability priorities
	1st priority	2nd priority	3rd priority	4th priority	5th priority	
management system of personal protective equipment such as firefighters' fire suits						
2. Training internal experts for firefighters and introducing and operating a system for firefighters to improve the management system of personal protective equipment such as firefighters' firefighting suits	0	0	0	0	1 time	1
3. Organize and systematically operate a pool of experts in the field of personal protective equipment such as firefighters' fire protection	0	0	0	0	0	0
4. Reinforcement of professional personnel for systematic operation and improvement of personal protective equipment management system such as firefighters' fire suits	0	0	0	0	0	0
5. Improving the firefighting personal protective equipment management system and securing a budget for systematic operation	0	0	0	2 times	1 time	5

▣ Improvement of management system for personal protective equipment such as turnout gear

Evaluation scale / Evaluation item	Priority result					Sum of practicability priorities
	1st priority	2nd priority	3rd priority	4th priority	5th priority	
6. In the disaster scene standard operation procedure (SOP 108, 200, 201), as a user at the stage of the disaster scene (fire, etc.) return procedure, the duty to remove contamination of personal protective equipment during firefighting activities is specified (command team leader or site safety inspector)	2 times	0	1 time	0	1 time	**14**
7. Disaster scene (fire, etc.) First decontamination of personal protective equipment at the scene due to the health impact of pollutants Addition of SOP (or manual) and training for fire suppression and rescue personnel	2 times	4 times	1 time	0	0	**29**
8. Development of training courses for improving the management system of personal protective equipment such as firefighters' fire suits and systematic operation	1 time	3 times	1 time	2 times	0	**24**
9. Conduct education on the risk of health effects of pollutants in the disaster scene (fire, etc.)	1 time	0	2 times	2 times	0	**15**

Evaluation scale / Evaluation item	Priority result					Sum of practicability priorities
	1st priority	2nd priority	3rd priority	4th priority	5th priority	
10. Distinguish non-contaminated areas and contaminated areas in the fire department, and propose a flow map for the movement of firefighters such as changing fire suits, decontamination, showering, washing personal protective equipment, and washing	0	0	1 time	0	2 times	5
11. Firefighting equipment organization (tentative name) established	0	0	0	0	1 time	1
▣ **Specific items such as number, use, wash of turnout gear**						
12. Revision to increase the basic amount of fire protection clothing	0	0	0	0	0	0
13. Revision of the safety and management manual for personal protective equipment including special fire protection	1 time	0	1 time	0	1	**9**
▣ **Law, regulation, program**						
14. Revision of the Law on Health and Welfare of Firefighting Officials reflecting the specificity of firefighters' work	0	0	0	1 time	0	2
15. Revision of standard operational procedures for	0	0	0	0	0	0

Evaluation scale Evaluation item	Priority result					Sum of practicability priorities
	1st priority	2nd priority	3rd priority	4th priority	5th priority	
disaster scenes (SOP 108, 200, 201)						
16. Revision or enactment of ordinances for installing administrative organizations in Seoul to open firefighting equipment organization	0	0	0	0	0	0

2.3.3.1.3 Outcomes of importance and practicability

As a result of the Delphi survey, the item with the highest 'importance' was '7. Conducting first-line decontamination training for personal protective equipment at the scene level according to the health impact of pollutants at the disaster scene', '9. Education on the health impact risk of pollutants at disaster scenes', '8. It was the item' Development of a curriculum for systematic application of the management system of personal protective equipment such as fire protection for firefighters.'

The average of the two items was 4.7 points, 4.9 points, and 4.6 points, respectively, and most of the respondents evaluated it as 'very important (5 points)'. In addition to '5. Secure fire fighting budget′. '11. Firefighting equipment organization (tentative name) newly established′, ′13. The item 'Revision of Safety and Management Manual for Firefighting protection suits' also received an average of 4.9 points, 4.7 points, and 4.7 points, respectively, in the 'importance' evaluation, and was recognized as a very important part. Except for the two items on the average of 3 points, most of the items received a fairly high score of 4 or more in terms of 'importance'. In addition, the three categories of organization, manpower, and budget all received an average of 4.5 points in 'importance', and were recognized as very important fields.

The highest item for ' practicability' is '7. First-line decontamination training for personal protective equipment at the site level according to the health impact of pollutants at the disaster scene′, ″8. Development of a curriculum for systematic application of the personal protective equipment management system, such as fire protection for firefighters,′, ″9. The average value of the item ″Education on the health impact risk of pollutants in the disaster site″ was evaluated as 4.9 points, and the feasibility was recognized as the highest.

This is thought to reflect the opinion that the proposals presented from the standpoint of real experts have high ″importance″, but may actually have difficulties in terms of ″practicability″.

Table 2-25. Delphi findings on importance and practicability

Evaluation item / Evaluation scale	Importance		Practicability	
	Mean	Median	Mean	Median
▣ **Organization, manpower, Budget field**				
1. Hiring professional personnel to improve the management system of personal protective equipment such as firefighters' fire suits	3.1	3	2.4	2
2. Training internal experts for firefighters and introducing and operating a system for firefighters to improve the management system of personal protective equipment such as firefighters' firefighting suits	4.3	4	3.6	4
3. Organize and systematically operate a pool of experts in the field of personal protective equipment such as firefighters' fire protection	4.4	5	4.0	4
4. Reinforcement of professional personnel for systematic operation and improvement of personal protective equipment management system such as firefighters' fire suits	3.3	3	2.3	2
5. Improving the firefighting personal protective equipment management system and securing a budget for systematic operation	**4.9**	**5**	3.7	4
▣ **Improvement of management system for personal protective equipment such as turnout gear**				
6. In the disaster scene standard operation procedure (SOP 108, 200, 201), as a user at the stage of the disaster scene (fire, etc.) return procedure, the duty to remove contamination of personal protective equipment during firefighting activities is specified (command team leader or scene safety inspector)	**4.7**	**5**	4.3	4
7. Disaster scene (fire, etc.) First decontamination of personal protective equipment at the site due to the health impact of pollutants Addition of SOP (or manual) and training for fire suppression and rescue personnel	**4.7**	**5**	**4.9**	**5**

Evaluation item / Evaluation scale	Importance		Practicability	
	Mean	Median	Mean	Median
8. Development of training courses for improving the management system of personal protective equipment such as firefighters' fire suits and systematic operation	**4.6**	**5**	**4.9**	**5**
9. Conduct education on the risk of health effects of pollutants in the disaster scene (fire, etc.)	**4.9**	**5**	**4.9**	**5**
10. Distinguish non-contaminated areas and contaminated areas in the fire department, and propose a flow map for the movement of firefighters such as changing fire suits, decontamination, showering, washing personal protective equipment, and washing	4.3	5	3.6	4
11. Firefighting equipment organization (tentative name) established	**4.7**	**5**	3.0	3
▣ Specific items such as number, use, wash of turnout gear				
12. Revision to increase the basic amount of fire protection clothing	4.1	4	3.3	3
13. Revision of the safety and management manual for personal protective equipment including special fire protection	**4.7**	**5**	4.3	4
▣ Law, regulation, program				
14. Revision of the Law on Health and Welfare of Firefighting Officials reflecting the specificity of firefighters' work	4.3	4	3.0	3
15. Revision of standard operational procedures for disaster sites (SOP 108, 200, 201)	4.1	4	3.6	3
16. Revision or enactment of ordinances for installing administrative organizations in Seoul to open firefighting equipment organization	**4.6**	**5**	3.0	3

2.3.3.1.4 Additional suggestions presented during the Delphi expert investigation process

In addition to evaluating the importance and practicability of each item, there are questions to write other opinions of experts, so opinions were freely collected. The main contents are as follows (Table 2-26).

Table 2-26. Additional expert opinion on system improvement (draft)

■ **Expert 1** - A manual and educational proposal for decontamination and management of fire fighting protection suit and other personal protective equipment is required. - When establishing the manual, it is necessary to prepare comprehensive classification standards and management plans that can reflect the characteristics of the scene such as reflecting the number of dispatches, the type of pollutant, and the difference according to pollution information. ■ **Expert 2** - The most important thing in the management of fire protection is the change of consciousness of firefighters. Changing corporate consciousness will be meaningful in terms of mid- and long-term management. ■ **Expert 3** - There is a need for sufficient manpower reinforcement by expanding and reorganizing the breathing control room, which is currently operating at two locations in Seoul, by region. - It is necessary to establish a special firefighting equipment maintenance organization (tentative name) for each area that performs professional cleaning and

maintenance work for fire protection after disaster response, reassignment after washing, and cleaning and equipment maintenance of personal protective equipment.

- It is necessary to design and operate a new construction fire station office by dividing contaminated, crossing, and non-contaminating areas inside the firefighting office by providing a flow line that can remove pollutants upon dispatch and return.

2.3.4 Discussion and Political Suggestions

The high importance and feasibility evaluation results in the policy system improvement plan of the Delphi survey based on surveys and experimental studies means that it is a relatively important and priority policy. Therefore, from now on, I would like to present recommendations on implementation plans for specific policies for each item that had a high score as a result of the Delphi survey and the results of overseas research.

2.3.4.1 The need to prepare environmental, legal/institutional and educational devices for decontamination of personal protective equipment such as fire protection at the stage of return to the fire scene

According to NFPA Code 1851, if equipment is cleaned quickly after a fire response, equipment life can be shortened, but firefighters can reduce the amount of pollution exposed. Currently, fire organization, including the National Fire Agency

(NFA) in South Korea do not have separate regulations related to occupational diseases or health of firefighters regarding the use of equipment at firefighting scenes.

Firefighters may recognize that the materials generated at the fire scene are harmful, but they are not aware that cross-infection through fire protection can affect personal health and pollute the air of the surrounding environment in fire fighting vehicles and fire departments.

In the United States and Europe, firefighters are performing gross decontamination using rinse or water to remove various harmful substances from personal protective equipment, including fire protection, during firefighting activities in the stage of returning to the fire scene. This is the first purpose of removing combustion substances, one of the immediate carcinogens after fire suppressing, overhaul, investigation and has the second significance of preventing cross-contamination.

The decontamination process occurs at incidents where firefighters have been exposed to products of combustion or contaminants. This is an effective way to remove harmful carcinogens from firefighters turnouts and help guard against cancer. Overseas studies have already recommended that gross decontamination should be performed indispensably at the fire scene because various hazardous substances are buried in the firefighting suit resulting from firefighting at the fire scene. However, there are no studies conducted in Korea on fire scene and firefighting protection suit contamination.

In spring, summer, and autumn, it is necessary to carry out gross decontamination to remove chemically hazardous substances from fire protection clothes with water using a fire hose, etc. at the stage of returning to the fire scene. Contaminants on personal protective equipment such as waterproof shoes and air respirators must be gross decontamination. In addition, after gross decontamination, it is recommended to store personal protective equipment such as fire protection in the outer space of the fire vehicle if possible. However, if it is not possible, it will have to be washed in a washing machine dedicated to fire suits after sealing them in a separate container. At this time, firefighters should be wearing protective clothing until the moment they start washing their fire suits. In addition, in winter, if gross decontamination with water is performed, it freezes immediately and injury damage due to falls is expected.

Using an air gun to remove substances from fire protection can trigger secondary cross-infection of chemically hazardous substances, and harmful substances can penetrate the skin through the inside of the fire protection and cause skin contamination. In addition, after firefighting activities, hand washing and showering are essential for removing contaminants as well as changing and washing fire suits quickly. Because according to Fent et al's research, it has been confirmed that a lot of contamination of the neck area of the face occurs while taking off the fire protection suit for field activities. Therefore, firefighters need to be aware of it and make it a habit.

According to Fent et al, it was emphasized that the fire protection clothing worn during fire fighting should be cleaned due to high contamination of the inner part of the wrist. In addition, some state firefighting headquarters in the United States emphasized that it is very important to create a culture that motivates and encourages firefighters themselves by teaching them to familiarize themselves with the seven steps of decontamination and to practice them, and by creating and providing checklists. The seven stages of decontamination below are SOG (Standard Operating Guidelines) that are actually being implemented, and it is necessary for domestic firefighters to comply with the decontamination principles.

ⅰ) Decontamination of severely contaminated equipment is performed at the fire scene.

ⅱ) Scrub and wipe on fire scene.

ⅲ) Replace the dirty hood with a clean one.

ⅳ) Contaminated equipment is bagged and sealed prior to departure from the site.

ⅴ) When you arrive at the fire department, clean your personal protective equipment.

ⅵ) Take a shower within an hour.

ⅶ) Do not store contaminated equipment in your own vehicle, and always use a protective case.

Lastly, the number of each individual statutory holding of fire protection suits prescribed in the Fire Protection Equipment Management Act of the Fire Service Administration is two sets. However, the suggestion obtained through our survey, experiment, and Delphi study is that the current two sets of fire protection suits have many limitations in performing on-scene firefighting activities while protecting the health and safety of firefighters. In particular, when field decontamination is performed, it is difficult to implement gross decontamination under the current legal holding standards for fire protection because it takes time to wash and dry fire protection clothes. Therefore, it is necessary to revise the number of domestic equipment management laws.

2.3.4.2 Preparation of on-scene firefighting activity regulations for gross decontamination

For the safety and health of firefighters, it is necessary to motivate firefighters who have been engaged in fire fighting activities to implement decontamination by institutionalizing the part where they must perform decontamination at the scene before returning. Currently, the Fire Service Administration is operating the standard operating procedure (SOP) corresponding to the stage of returning to the fire site among the standard operation procedures at the disaster scene, but there is no content on the scene decontamination and needs to be revised. Among the standard operational procedures at disaster scenes, revisions are necessary in 『SOP 108 Dispatch Return Procedure』, 『SOP 200 Common Standard Operation Procedures for Fire Response』, 『SOP 201 Standard Operation Procedures for Fire Response Safety Management』. It is as follows (Table 2-27, Table 2-28, Table 2-29).

Table 2-27. Disaster scene standard operation procedure (SOP) 108 squad return procedure

SOP 108 Procedure for returning to the squad (current)	**SOP 108 Procedure for returning to the squadron (requires revision)**
1. Commander's evacuation procedure	1. Commander's evacuation procedure
1.1 The commander of each squadron who has been ordered to withdraw must report on-scene withdrawal to the general situation room after inspecting personnel and equipment, and command the movement to the relevant government office.	1.1 Each squadron commander and on-scene safety officer (or safety officer) who received an order to withdraw controls and manages on-scene decontamination of all personal protective equipment worn by the members of the fire scene.
1.2 Each ambulance commander who returns to the fire station or the 119 Safety Center should perform as top priority tasks such as filling and refueling fire fighting vehicles, cleaning and charging air ventilators, charging batteries, replenishing consumables, and replacing and drying fire hoses.	1.2 After inspecting personnel and equipment, each squadron commander must report on-scene withdrawal to the general situation room and command the movement to the relevant government office, and manage safety such as compliance with traffic laws until return.
	1.3 Same as 1.2 on the left
3. Equipment inspection procedure	3. On-scene decontamination and equipment inspection procedures

SOP 108 Procedure for returning to the squad (current)	SOP 108 Procedure for returning to the squadron (requires revision)
before returning to the squadron 3.1 Make sure that no equipment is left at the disaster scene, and quickly grasp the amount of equipment that is broken or lost and the amount of items consumed so that there is no disruption in preparation for dispatch. 3.2 The commander of the unit reports the presence or absence of equipment abnormality to the commander by verbal or wireless communication. 3.3 Contaminated equipment is purged at the scene prior to evacuation, if possible.	before returning to squad 3.1 Equipment worn and used at the disaster scene performs decontamination of severely contaminated equipment at the site before departure. 3.1.1 Scrub the equipment in the field and replace the soiled hood with a clean one. 3.1.2 Before leaving the site, pack the contaminated equipment in a pack, seal it, and load it outside the fire truck. 3.1.3 Wash immediately when you return to the fire department. ※ Modify left 3.3 as above 3.2 Same as 3.1 on the left 3.3 Same as 3.2 on the left

Table 2-28. Return Stage of the Disaster Scene Standard Operation Procedure (SOP)

SOP 200 Common standard operational procedures for fire response (current	SOP 200 Common standard operational procedure for fire response (revision required)

4. Return stage 4.1 The unit commander or senior officer of each unit shall report to the commander after identifying the physical abnormalities of all members of each unit and whether there is any abnormality in the field response equipment 4.2 Final confirmation of site safety	4. Return stage <u>4.1 On-scene decontamination is carried out at the fire scene under the control of unit commanders or safety officers for each squadron.</u> <u>4.2</u> Same as 4.1 on the left <u>4.3</u> Same as 4.2 on the left

Table 2-29. Disaster scene standard operation procedure 4. Return stage of (SOP) 201

SOP 201 Fire Response Safety Management Standard Operation Procedure (Current)	**SOP 201 Fire response safety management standard operation procedure (revision required)**
4. Return stage 4.1 Safety measures at the fire scene are handed over to relevant organizations (local government, police, related persons, etc 4.2 Safety check of crew and field response equipment	4. Return stage 4.1 Same as 4.1 on the left <u>4.2 On-scene decontamination is carried out at the fire scene under the control of unit commanders or safety officers for each squadron.</u> 4.3 Same as 4.2 on the left

2.3.4.3 The fire Academy curriculum reflects the health impact of the disaster scene and gross decontamination

In the curriculum for new firefighters in provincial fire academy including the national fire academy, decontamination education and training conducted after fire suppression or live fire drills were confirmed. In some firefighting academy, gross decontamination was dealt with in theoretical education, but there were no educational institutions offering practical training. Therefore, it is necessary to include decontamination training in the curriculum such as fire fighting training and live fire training in fire academy. A curriculum for instructors must be opened and operated in advance. In addition, education on the health effects of combustion by-products occurring in disaster scenes such as fires should be conducted in parallel to motivate the importance and practice of such decontamination on scene.

2.3.4.4 Revision of safety management manual for fire protection suit and training

Currently, there is a safety management manual for fire protection suit that was published by the fire department and distributed nationwide. According to the safety management manual for fire protection suit, it is recommended to wash with a washing machine at least every 6 months. However, according to the NFPA Code, it is recommended to wash in a washing machine for fire protection suit after fire fighting activities at the fire scene. Therefore, it is necessary to revise the standards for the fire protection clothing washing machine standard of the fire department.

In addition, according to the survey results of this study, it was analyzed that 55% of the survey respondents did not accurately recognize the safety management manual of fire protection clothes, including the drying method after washing special fire protection clothes. Therefore, it is necessary to actively conduct education on safety management manuals such as how to build fire protection for firefighters.

2.3.4.5 Designated and operated as a professional laundry and repair company specialized in fire protection suit

First, the current fire protection suits are washed using a washing machine dedicated to fire clothes according to a specialized washing method. However, if the degree of contamination is high at the firefighting activity scene such as a fire, there is a possibility that residual contaminants may remain in the fire suit due to limitations in self-cleaning.

Second, fire protection suit is an item that is produced collectively by unit size. In addition, fire protection clothing may cause fabric damage such as fraying or tearing during use. In the case of some firefighters, there is a case of adjusting the supplied fire protection clothing to suit their body size at a general clothing repair shop. However, since fire fighting protection suits are clothes worn at the fire scene, protection performance from fire can be maintained only by professional repairs using aramid or PBI material with flame retardant performance. Therefore, there is a need for a system capable of statistically systematic and professional management of fire protection clothes, such as professional washing and repair of contaminated fire protection clothes at the fire scene. In fact, in Australia and other foreign countries, fire protection suit is being washed and repaired by external specialized companies, increasing work efficiency and promoting personal hygiene and health for firefighters. In Korea, some fire departments are implementing the above policy. As a result, compliance and satisfaction were found to be very high in terms of convenience of work, increased efficiency, and safety of fire fighting protection clothing. Therefore, it is necessary to introduce a fire fighting protection suit management and operation system through professional consignment projects at the national level.

2.3.4.6 Space organization, arrangement, and fire protection suit management and operation to block the inflow of harmful substances in the fire department

According to previous studies, it was confirmed in domestic environmental studies that there is a possibility of contaminating indoor air quality through fire fighting vehicle boarding and fire fighting activities while wearing fire protection suits for field activities. Washing and cleaning of fire engines, fire suits, and personal protective equipment used by dispatching to disaster scenes such as fires is one of the main functions of contaminated material control.

Decontamination protocols in fire departments are the best way to ensure that decontamination procedures are carried out upon return from the accident scene. Therefore, fire departments should be zoned for each function. According to the NFPA Code, it is necessary to design and operate fire fighting offices by dividing them into hot zones, warm zones, and cold zones according to the degree of exposure to harmful substances such as carcinogens.

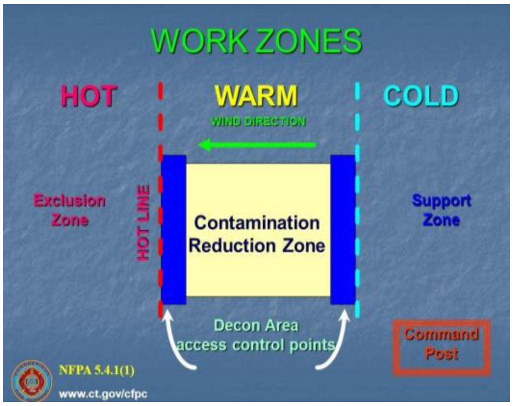


Figure 2-16. Hot Zone Design Conceptual Frame in Fire Station

This is stipulated in the recently enacted Fire Service Directive No. 135, Regulations on Site and Building Standards for Fire Departments (2019), but functional requirements for each area are not included. Therefore, according to the three concepts, it is necessary to carry out second decontamination after returning to the fire station and to move to the office, and to organize the space of the fire department zoned accordingly, and training for employees who are users of the fire department is also necessary. The components and functions of each zone within the fire fighting complex are as follows ;

ⅰ) Hot zone

- Garage, admiral room, fire suit storage, equipment washing room, etc.
- Clean personal protective equipment including fire protection clothing used on scene.
- Remove contaminants from the body by taking a shower in an independent toilet equipped with a shower facility.
- Do not take equipment or personal protective equipment to other areas. In addition, there should be clear signs within the area informing you to wash and disinfect your hands.

ⅱ) Warm zone (=Transitional zone)

- It includes passages, entrances, and corridors that are buffer spaces that are boundary areas.
- Hand wash sinks, hand sanitizers, and mats to remove dust are installed in this area.
- Do not allow carcinogenic harmful substances in the hot zone to enter the space as much as possible.

ⅲ) Cold zone

- This includes accommodations, lounges, and offices.

- Place and wash laundry rooms used for personal purposes, including clothes and supplies not related to movement.

- The ventilation system must be designed to provide positive pressure to generate air flow from the cold zone to the hot zone.

2.3.4.7 Improvement of management and operation of fire fighting protection suit

Fire fighting protection suits should be stored in a well-ventilated area. However, in the case of Korea, most of the fire protection clothing storage areas are closed-type wardrobes, so the fire protection clothing and personal protective equipment are stored inside the closet. In this case, there is a problem in terms of industrial hygiene ventilation because it is a structure that is not ventilated at all, and contaminated and non-polluted fire protection clothing is often stored together. Therefore, it is important to avoid storing fire fighting clothing in a closed closet-type space. This is because it promotes the accumulation of contaminants and the development of fungi in the fire suit. In the case of overseas, a dedicated storage warehouse space for fire protection is installed and managed in an open-type zone inside the fire department. Therefore, it is necessary to improve the equipment storage location and management method.

In addition, the equipment storage room should be arranged on the movement line inside the garage on the first floor as possible for quick dispatch and convenience when returning, and the hot zone and warm zone should be managed separately.

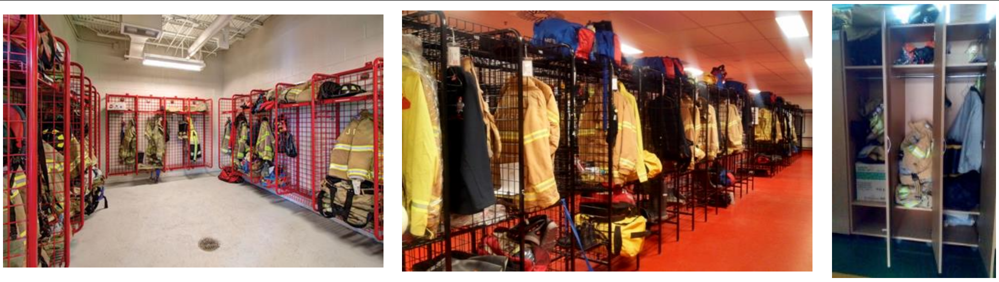


Figure 2-17. Status of storage warehouses for fire protection clothing, USA (left), Australia (middle), South Korea (right)

2.3.4.8 New establishment and operation of national firefighting equipment maintenance organization (tentative name) for systematic management and operation of personal protective equipment including fire protection

This study is a series of studies to improve awareness of the use and management of fire fighting protection suit through health awareness results on the use and management of fire protection suit, primary and secondary contamination levels at the fire scene, and to resolve the contamination of fire protection clothing policy. Fire fighting protection suit management is intertwined with aspects that must be managed at the level of personal protective equipment. Therefore, it is necessary to organize a firefighting equipment maintenance organization (tentative name) for systematic management of personal protective equipment.

Fire fighting equipment maintenance organization (tentative name) refers to a place that functions as equipment purchase, maintenance, simple repair, and replacement for smooth supply and management of fire-fighting equipment and fire fighting vehicles in all areas of fire, rescue, and emergency medical services. Currently, in Korea, only some functions such as fire vehicle or equipment maintenance are performed in three places in Seoul, Busan, and Gyeongbuk province. The reasons for differences in operating methods such as size and function are due to the limitations of manpower and budget. In order to operate the firefighting equipment maintenance organization (tentative name), it is necessary to expand the manpower and budget through the establishment of an organization and amendment of related laws necessary for operation.

2.4 Limitation and Strength

This study assumed the combustion situation in case of fire in a private housing as the environment. Due to the limitation of the size of the temporary building that does not reflect the actual size of the house, it was not possible to burn sufficient types and actual amounts of combustible materials from combustion materials. Accordingly, the amount of chemical pollutants generated from the resulting ignition material would have been detected somewhat less than in the actual fire situation. Therefore, it can be presumed that both the amount of hazardous substances measured at the first fire scene and the amount of hazardous substances detected in the second fire fighting protection suit were underestimated. Therefore, it will not be possible to generalize the measurement results of this study into the types and amounts of combustion substances generated in a residential fire environment.

However, it can be of great significance that it is the first research conducted in the world to simultaneously measure the types and amounts of the primary pollutants generated at the fire scene and the pollutants that can cause indoor and outdoor pollution by being contaminated with fire suits again. In addition, it is meaningful in that the effect on the air as well as the water quality was analyzed by performing water analysis as well as air capture analysis for pollutants buried in fire fighting protection suit. As a result, it was confirmed that the amount exceeding the water quality conservation method for the four water quality analysis items was confirmed, which shows the need for a follow-up study on how much affects water pollution depending on the presence or absence of on-scene decontamination of fire protective clothing.

In addition to residential fires, research on pollution at fire scenes is conducted in various places such as hospitals, factories, and vehicles in the future. And, by linking this with epidemiologic studies, it will be possible to present the relevance of disease outbreaks in the future. Due to the heat generated during combustion due to the environment in which the door is closed and measured during the fire measurement stage of the temporary building, the temperature inside the temporary building and the harmful factors generated could not be measured directly. In this study, the personal exposure concentration reflecting the personal exposure of firefighters was not accurately reflected because local sampling was performed rather than individual sampling. Due to the absence of a separate fire protection suit reserved for research and the absence of a separate research budget, this study was conducted with the cooperation of fire protection clothes from the front line fire department. In this process, fire fighting protection suits manufactured six years ago were used, not the latest fire fighting protection suits.

2.5 Conclusion

As the exposure level of hazardous substances is measured at a high level at fire suppression scenes, health effects are expected from the long-term accumulation of exposure of hazardous substances by firefighters. Therefore, personal protective equipment must be thoroughly worn at the fire fighting scene. In addition, cross-contamination of harmful substances on fire protection during fire fighting activities at the fire scene was confirmed in this study. Besides, before returning to the fire station, gross decontamination of personal protective equipment including severely contaminated fire protection is required at the fire fighting scene. For systematic implementation of gross decontamination, revision of related regulations, user education, and decontamination equipment are necessary.

Furthermore, it is necessary to induce practical training, habituation, and change of perception through education. It is imperative to prevent shortening of the life of equipment by letting employees know how to use and wash the fire protection through training in the safety management manual for fire protection. The firefighters' personal hygiene and health promotion effects can be expected by increasing the efficiency and concentration of work through the establishment and operation of a consignment management system for firefighters. For safe firefighting activities through gross decontamination, it is necessary to secure firefighters' safety, improve field work efficiency, and establish a basis for securing budgets through reorganization of the integrated fire protection management system.

Finally, it is necessary to organize and arrange spaces to block the inflow of carcinogenic and hazardous substances into the fire department in the fire station return stage, and this should be reflected from the fire department building design stage.

Chapter Ⅲ. Characterization of Secondary Exposure to Chemicals and Indoor Air Quality in Fire Station[3]

[3] This chapter has been published in Fire Science and Engineering 2019 in press [DOI: https://doi.org/10.7731/KIFSE.2019.33.4.140].

3.1 Introduction

When a fire occurs, carcinogens such as benzene, 1,3-butadiene, and formaldehyde (HCHO) are generated, and exposure to high concentrations in a short period of time is possible. Fire suppressing, overhauling, investigating firefighters tend to have several types of cancer, and the occupational exposure of firefighters in charge of firefighting duties was designated as Group 2B by the International Cancer Institute (IARC) [14]. The exposure of firefighters to harmful factors at the fire scene is difficult to measure due to the nature of the fire scene, so research around the world is insufficient. In the event of a fire, various chemical substances and smoke may occur through complete combustion or incomplete combustion [14]. Hazardous substances generated at the fire scene are polycyclic aromatic hydrocarbons (PAHs), nitro-PAHs, aldehydes, cyanides, acids, particulate matter, nitrogen, sulfur, carbon dioxide, carbon monoxide, nanoparticles and vinyl from combustion. Chloride, polychlorinated biphenyls (PCBs), phthalates, isocyanates, vinyl chloride monomers (VCM), etc., and are substances that cause carcinogenesis, respiratory and skin irritation, and poisoning [36].

In Korea, firefighters' exposure to hazardous substances was confirmed through the risk of exposure to asbestos exposed during firefighting field activities [37], and the characteristics of chemical hazards that are primarily exposed during fire investigation and debris cleaning at the fire scene [38]. The health risks of firefighters were confirmed through exposure assessment at the stage of fire suppression, overhaul and fire investigation at the scene [39]. When firefighters return to the fire brigade after extinguishing the fire, and enter the fire brigade indoors, various hazardous substances exposed at the fire scene are spread to the interior of the fire brigade through fire fighting protection suits, helmets, extinguishing equipment, and fire fighting vehicles dispatched to the scene. This is called secondary exposure. Despite the fact that the research on the development of facilities and firefighting equipment management standards to block secondary exposure to harmful factors in the fire department has already been carried out and the research results have been published [40], the government or It is not being done properly at the local government level. The fire brigade is a working environment space where firefighters perform their duties, as well as a space where citizens and other citizens visit for civil affairs, or citizens of various age groups visit for fire life and safety education and safety experiences. Therefore, there should be no effect on the human body by exposure to harmful substances. In Korea, there are still no investigations from various angles on how directly or indirectly exposed to which chemical substances while firefighters perform fire fighting in various places. The indoor space of the fire brigade, where firefighters spend most of their time in addition to fire fighting and rescue activities, is likely to be additionally exposed to hazardous factors related to fire suppression in addition to the harmful factors that may occur in general buildings.

3.2 Study Objective

The purpose of this study is to evaluate the indoor air quality of the fire fighting office where firefighters returned fire station after the fire fighting activities were completed by dispatching to the fire scene, and to evaluate the indoor air quality of the inside of the fire fighting vehicle that firefighters boarded after returning fire station. In addition, this study aims to provide policy recommendations along with management to maintain the safe range of indoor air quality within the fire station, as well as measures to take when returning home after firefighting activities at the fire scene, through the results of indoor air quality measurement in the fire station.

3.3 Methods and Materials

3.3.1 Study Design

This study was a prospective randomized experimental study, and four fire departments located in Seoul Metropolitan were randomly selected. Among them, two fire departments (A, B), which are experimental groups, were tested at the fire scene and measured air quality after returning to the fire station, and the other two fire departments (C, D), which are control groups, were at the usual level (Baseline) air quality was measured. At this time, A and B returned to the fire station within 20 minutes when the overhaul work was completed at the fire scene, and the indoor air quality measurement started immediately. At the same time, the construction year, area, ventilation condition, and garage area were investigated along with the characteristics of each fire station.

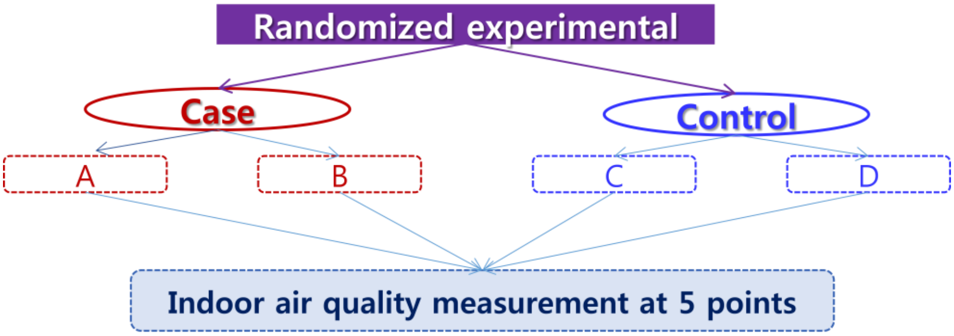


Figure 2-18. Experimental design in this study

3.3.2 Study Period

From November 1st to November 30th, 2016, the Seoul Metropolitan using fire safety map computer system was used to monitor all fire accidents received from Seoul Metropolitan Government to the General Disaster Prevention Center for 24 hours. It was determined whether indoor air quality can be measured through monitoring of on-scene activity conditions such as fires in which fire departments are dispatched) and fire suppression.

3.3.3 Measurement and Analysis

3.3.3.1 Measurement and Data collection

The indoor air quality was measured by designating five points in each of the four fire departments, including the fire department garage, the on-scene response team office and waiting room, the fire fighter waiting room, fire investigation and detection office space, and command vehicle (Table 3-1). 11 hazardous substance items such as particulate matter, formaldehyde, volatile organic compounds, PAH, VCM, acidity, asbestos, CO_2, NO_2, O_3 were measured according to the process test method. In particular, when fire investigation and detection work is completed, the person in charge of fire extinguishing plays a role of identifying and identifying the cause of the fire during the overhaul process. Hazardous substances are exposed during the overhaul process. In most cases, work is performed while wearing only clothes and dust masks. Total floating bacteria, which are the main causes of radon and indoor organic substances, which are not a big problem in ground buildings, were excluded from the measurement.

Table 3-1. Measurement site of indoor air quality in fire station

No	Air Quality Measurement Sites
1	Behind the Fire Stations Garage (Fire Vehicle Real Area Wall)
2	119 Center Office and Waiting Room
3	Fire Fighter Waiting Room
4	Fire Investigation and Inspection Office Room
5	Fire Command Vehicle Indoor

In addition to indoor pollutants, items such as PAHs, VCMs, and acids (hydrochloric acid, nitric acid, phosphoric acid, sulfuric acid), which are highly hazardous among substances that can occur at the fire scene, were added [41]. Finally, the pollutant items for each item were measured and compared with the normal range for each item applied mutatis mutandis at national and abroad, and the results were presented.

3.3.3.2. Analysis

3.3.3.2.1 Particulate Matter (PM 10, PM 2.5)

It was measured in accordance with ES 01354.1, the environmental air dust measurement method of the air pollution process test standard. Particulate matter (PM10, PM2.5) was measured through a light scattering method (Grimm Dust Spectrometer 1.108, Grimm GmbH, Germany). With a direct-read particulate matter meter using a light scattering method using a laser, particulate matter having a size of 0.3 μm-20 μm was measured by size through 15 channels.

3.3.3.2.2 Formaldehyde

Formaldehyde emission measurement method ES 02601.1 and National institute for occupational safety and health, manual of analytical methods (NIOSH NMAM) 2016 were used according to the indoor air quality process test standard of the

Ministry of Environment. Formaldehyde was collected by connecting a pump calibrated at a flow rate of about 0.5 L/min to a cartridge coated with 2,4-dinitrophenylhydrazine equipped with an ozone scrubber, and was measured twice for about 30 minutes. In addition, the pump was used by correcting the flow rate before and after collecting the sample, and the cartridge from which the sample was collected was refrigerated until analysis. In addition, for the analysis of the pre-treated sample, high performance liquid chromatography/Ultra-violet detector (HPLC/UV) was used (Wates 2695/2487, USA). Acetonitrile (100%) and tetrahydrofuran (20% Tetrahydrofuran in Distilled Water) were used as the mobile phase (Eluent), and degassed using a filter paper and an ultrasonic device were used. In addition, in order to increase the reliability of the analysis results, quality control of analysis data for sample preparation and instrument analysis was performed.

The limit of detection (LOD) for formaldehyde was a value obtained by three times the standard deviation of the concentration value by repeatedly analyzing the lowest level in the standard solution 7 times, and was 0.0025 μg/sample. Desorption efficiency experiments were prepared at two concentration levels, such as low concentration (0.2 μg) and high concentration (1.0 μg), for each concentration level, and the desorption efficiency of formaldehyde using a 2.4-DNPH cartridge was 116.0 ± 7.7%.

3.3.3.2.3 Volatile organic compounds (VOC)

It was measured using ES 02602.1, the measurement method of volatile organic compounds released from the interior and building materials of the Ministry of Environment. It was collected by connecting a low flow pump calibrated to a flow rate of about 0.05 L/min to a solid adsorption pipe filled with Tenax TA, and measured twice for about 30 minutes. The pump was used by correcting the flow rate before and after sample collection, and the solid adsorption tube from which the sample was collected was stored refrigerated until analysis. The analysis was carried out using a thermal desorption device (TurboMatrix 350 ATD, PerkinElmer, USA), and the sample desorbed from the adsorption tube was analyzed by gas chromatography/mass spectrometry (GC/MSD, QP-2010 ultra, Simazu, Japan) SCAN mode, and analyzed chromatography. Gram was qualitatively analyzed using Wiley 9 and NIST14 databases.

3.3.3.2.4 Polycyclic aromatic hydrocarbons (PAHs)

PAH was measured and analyzed using NIOSH NMAM 5515, and a total of 16 types of PAH were measured. With the tube connected to the Teflon filter (FILTER + SORBENT TUBE: 37 mm, 2 μm, PTFE + washed XAD-2, 100 mg/50 mg), a high flow pump calibrated to a flow rate of approx. 2 L/min is connected and collected. The pump was used by correcting the flow rate before and after sample collection, and the adsorption tube from which the sample was collected was refrigerated until analysis. In addition, the pretreatment-completed sample was analyzed in SIM mode with a gas chromatography/mass spectrometer (GC/MSD, QP-2010 ultra, Shimazu, Japan) equipped with AutoSampler (AOC-20i, Shimazu, Japan).

3.3.3.2.5 Vinyl chloride (VCM)

The vinyl chloride was measured and analyzed using NIOSH NMAM 1007, and a low flow rate pump adjusted to a flow rate of about 0.05 L/min was connected to an activated carbon tube to collect. In order not to exceed the breakthrough capacity, it was measured twice for 2 hours each, and the pump was used by correcting the flow rate before and after collecting the sample. The activated carbon tube from which the sample was collected was stored refrigerated until analysis, and analysis was performed using a gas chromatography/flame ionization detector (GC/FID, Agilent 6890, Agilent, USA).

3.3.3.2.6 Acids

The acid flow was measured and analyzed using NIOSH NMAM 7903. A low flow rate pump calibrated to a flow rate of about 0.2 L/min was connected to the silica gel tube, and the pump was used by calibrating the flow rate before and after sample collection, and the activated carbon tube from which the sample was collected was stored refrigerated until analysis. In addition, ion chromatography (IC, Thermo DIONEX ICS-1100, USA) was used for analysis of the sample after the pretreatment was completed. As the mobile phase, 1.7 mM $NaHCO_3$ + 1.8 mM Na_2CO_3 was used, and degassed with an ultrasonic device was used.

3.3.3.2.7 Asbestos

The method of measuring asbestos in indoor air by the Ministry of Environment (ES 02304.1) was used. A filter paper made of cellulose ester (MCE, Pore 0.8 μm, 25 mm) was mounted on a filter paper holder for collecting asbestos and collected by connecting a high flow pump adjusted to a flow rate of about 4 L/min. The pump was used by correcting the flow rate before and after sample collection. In addition, asbestos and fibrous dust in indoor air were collected on a filter paper, pretreated transparently, and then counted with a phase contrast microscope to analyze the number of asbestos and fibrous dust in the air.

3.3.3.2.8 CO, CO_2, NO_2, O_3

Carbon monoxide, carbon dioxide, nitrogen dioxide, and ozone were measured using direct reading equipment. Direct reading equipment is a device that can check the level of change in concentration over time using the principle of non-dispersive infrared (NDIR) or photoionization detection (PID). The direct reading equipment used for measurement is IAQ-CALC (Model 7545, TSI, USA).), GrayWolf (Model

TG-501, 502, Graywolf sensing solution, USA) was used.

3.4 Results

3.4.1. Status of basic ventilation facilities in the interior space of the fire department of 4 fire stations

Table 2 shows the basic status of the four fire departments that conducted an indoor air quality measurement survey in this study. The four fire stations were built from 1993 to 2012. In terms of the area of the fire station building, fire station C built in 1996 was the largest, and fire station B built in 2006 was the narrowest. Fire stations C and D differed in garage area, ventilation, and operation of exhaust ventilation facilities, although the number of vehicles possessed was similar to that of the construction year. Fire stations C and D built in the 1990s had half the number of garage fingerprints than fire stations A and B built after the 2000s, but the number of windows and ventilation fans increased in the more recently built fire stations (Table 2).

3.4.2. Indoor air quality measurement result of the fire station building

Table 3 shows an overview of the indoor air quality measurement at the fire station.

3.4.2.1. Particulate Matter (PM10, PM2.5)

Table 4 shows the average concentration of PM10 measured at five points in the fire department. Among the measurement results, the indoor environmental standard for PM10 did not exceed 150 μg/m^3. In addition, the concentration level of each area of PM2.5 was mostly lower than the atmospheric standard of 50 μg/㎥ (24 hours).

Table 3-2. Demographic findings of major facilities in fire stations

Distribution		Fire Station			
		A (Case)	B (Case)	C (Control)	D (Control)
	Built year*	2012	2006	1996	1993
Area (Unit: ㎡)	119 Center Office	80.3	70	241	121
	Fire Investigation Office**	66.42	22	241	13
	Fire Investigators Waiting Room	18	10	18	13
	119 Emergency Dispatch Center	66.42	66	160	35
	Garage	538.4	555	844	495
Window·Ventilation Fan/Door (Unit: Number)	119 Center Offices	21/3	14/2	4/2	5/3
	Fire Investigators Waiting Room	3/1	1/1	2/1	3/1
	119 Emergency Dispatch Center	8/1	4/1	4/1	6/1
Garage (Unit: Number)	Garage Door***	7	7	4	4
	Ventilating Shaft†	0	2	1	0

Distribution	Fire Station			
	A (Case)	**B (Case)**	**C (Control)**	**D (Control)**
Smoke Eliminating Facility‡	3	0	4	6
Number of Fire Engine¶	24	12	18	20

*Built Year : The Year of Completion of the Initial Fire Station, In Case of Reconstruction, the Year of Completion at the Time of Reconstruction.

**Field Command Team : Area of the Office Space Occupied by the Personnel Carrying out the Fire Investigation Work.

***Garage Door : Doors Installed to Distinguish the Outside from the Garage.

†Ventilating Shaft : Ventilation Facility Installed in the Ceiling of the Garage and Included Air Supply and Air Exhaust.

‡Smoke Eliminating Facility : Ventilation Facility Installed in the Ceiling in the Garage Without Vent.

¶Number of Fire Engine : Vehicles Owned by Fire Stations that are Regularly Stored Inside the Actual Fire Station Building.

Table 3-3. Overview of Indoor Air Quality Measurement in Fire Station

		Measurement Objective Measurement Date Measurement Time	A 11/11 11:04~18:30	B 11/24 15:37~23:26	C 11/25 10:06~16:36	D 11/25 19:17~02:10	Sample	Total
Method & Pollutants	Real Time Monitoring	PM10	5	5	5	5	-	20
		PM2.5*	4	5	5	5	-	19
		CO2†	4	4	4	4	-	16
		CO	5	5	5	5	-	20
		NO2	5	5	5	5	-	20
		O3‡	5	4	4	4	-	17
	Active Sampling	HCHO	10	10	10	10	3	43
		VOC	10	10	10	10	3	43
		Asbestos	5	5	5	5	3	23

Measurement Objective	A	B	C	D		
Measurement Date	11/11	11/24	11/25	11/25	Sample	Total
Measurement Time	11:04~18:30	15:37~23:26	10:06~16:36	19:17~02:10		
PAHs	5	5	5	5	3	23
Acid	5	5	5	5	3	23
VCM	10	10	10	10	3	43

*Data Logging has not been done Due to Problems Such as Battery in some Sections. A When Measuring Fire Station PM10, Equipment That Matched the Vehicle: 14:31-15:41, Equipment That was in Comprehensive Situation Room: 15:41-15:53

**Measuring Equipment That Fits the a Fire Department Garage is Equipment That Measures PM10, PM2.5 is not Measured..

†For CO2, Four Data are not Stored due to Abnormality of Equipment in the Equipment That Measured at each Fire Station. A Fire Office 119 Center Office (Office 2) CO_2, Equipment is Turned off due to Battery Problem (13:14-13:38) Data Logging does not Work.

‡An Error Occurred in One of the Instruments Measured by Four Fire Stations. Therefore, O_3 was not Stored in Three Locations, Including a Fire Station

Table 3-4. Average Concentration Level of PM10 by Area in Fire Station (Unit: ㎍/㎥)

Fire Station	Vehicle	Garage	Waiting Room	Office Room1*	Office Room1**
A	64.5	96.5	45.1	63.6	64.8
B	38.8	52.8	22.7	23.3	26.8
C	30.7	38.6	20.2	16.1	18.1
D	42.9	44.0	20.4	24.1	30.2

*Office Room 1: Emergency Dispatch Center Office

**Office Room 2: 119 Center Office

3.4.2.2. Formaldehyde (HCHO)

Table 5 shows the concentration of formaldehyde measured in each area of the fire department. There was no case of exceeding the indoor environmental standard of 100 ㎍/㎥ for formaldehyde. The highest concentration in Fire Station A was 98.6 ㎍/㎥, 20.3 ㎍/㎥ in Fire Station B, 30.7 ㎍/㎥ in Fire Station C, and 26.0 ㎍/㎥ in Fire Station D.

3.4.2.3. Total Volatile Organic Compounds (TVOC) and Volatile organic compounds (VOCs)

The concentration level of total volatile organic compounds measured in each area of the fire department exceeded 500 ㎍/㎥, which is the standard for total volatile organic compounds determined by the indoor standard in the garages of fire departments A and C (Table 3-6). In addition, in the case of toluene and normal-hexane, which are volatile organic compounds, relatively high concentration levels were found in the garage of fire station A and the garage of fire station C, compared to other substances, and fire station C had equipment fuel storage bins left in the garage (Table 3-7).

3.4.2.4. Polycyclic aromatic hydrocarbons (PAHs)

A total of 16 types of polycyclic aromatic hydrocarbons were analyzed, but no carcinogenic polycyclic aromatic hydrocarbons were detected, and naphthalene was the only polycyclic aromatic hydrocarbon type detected. In addition, the only detected naphthalene concentration was also lower than the exposure standards of the Ministry of Employment and Labor (Table 3-8).

3.4.2.5. Vinyl chloride (VCM)

As a result of analysis of vinyl chloride measured in each area of the fire brigade, it was not detected in all samples (Table 3-8).

3.4.2.6. Acid

It shows the concentration level of acid measured in the four fire department buildings. The concentration of gaseous sulfuric acid measured at the fire station's garage exceeded the exposure standard of 0.2 mg/m^3 of the Ministry of Employment and Labor. The concentration of acid measured in most areas was very low compared to the exposure standards of the Ministry of Employment and Labor (Table 3-8).

Table 3-5. Concentration Distribution of Formaldehyde by Area in Fire Station

Measurement Date	Fire Station	Measurement Site	Measurement Start Time	Measurement End Time	Concentration (㎍/㎥) (Indoor Criteria of Ministry of Environment: 100 ㎍/㎥)	
					Value	Mean
2016.11.11	A	Garage	12:20	13:08	7.6	53.1
2016.11.11	A	Garage	13:18	14:08	98.6	
2016.11.24	B	Fire Command Vehicle	15:57	17:46	20.3	17.6
2016.11.24	B	Fire Command Vehicle	17:53	20:25	15.0	
2016.11.25	C	119 Emergency Dispatch Center	10:57	11:37	26.4	28.5
2016.11.25	C	119 Emergency Dispatch Center	11:38	12:32	30.7	
2016.11.25	D	Waiting Room	20:02	20:37	24.2	25.1
2016.11.25	D	Waiting Room	20:40	21:06	26.0	

Table 3-6. Concentration Level of TVOC by Area in Fire Station

Fire Station	Measurement Site	㎍/㎥	
		Value	**Mean**
A	Fire Command Vehicle	4,497.3	2,483.9
A	Fire Command Vehicle	470.6	
A	119 Emergency Dispatch Center	-	2,041.2
A	119 Emergency Dispatch Center	2,041.2	
A	Fire Inspection Waiting Room	639.6	1,512.1
A	Fire Inspection Waiting Room	2,384.6	
A	119 Center Office Room	569.8	574.2
A	119 Center Office Room	578.6	
A	Garage	1,003.7	1,377.0
A	Garage	1,750.3	
C	Garage	779.6	679.5
C	Garage	579.3	

Table 3-7. Concentration Level of VOC by Area in Fire Station

Site	Fire Station	Pollutant	Occupational Exposure Limit by TWA		Concentration (unit: ㎍/㎥)	
			ppm	㎎/㎥	Results	Mean
Garage	A	n-Hexane	50	180	543.41	423.42
					303.43	
	C				392.03	334.89
					277.74	
	A	Toluene	50	188	360.59	288.25
					215.92	
	C				253.78	225.26
					196.74	

3.4.2.7. Asbestos

Asbestos was measured and analyzed in all four fire departments at the concentration of asbestos measured in each area of the fire department, and did not exceed 0.01 f/cc, the indoor environmental standard of the Ministry of Environment and Ministry of Employment and Labor (Table 3-8).

3.4.2.8. CO, CO_2

The concentration of carbon monoxide measured in each area of the fire brigade did not exceed 10 ppm, the indoor standard of carbon monoxide in all areas of the four fire stations. As a result of the carbon dioxide exposure evaluation, most of the indoor environment standards did not exceed 1,000 ppm, except for places where no measurement records were left due to some equipment errors, but exceeded the standards in some waiting rooms and offices (Table 3-9).

3.4.2.9. NO_2, O_3

Nitrogen dioxide levels were lower than the levels set by the Ministry of Environment and Ministry of Employment and Labor for the concentration of nitrogen dioxide in the indoor environment as a result of the measurements of all four fire departments. Except for the analysis results measured in the fire station's waiting room, the ozone concentration detected in most places was very low or not detected.

Table 3-8. Concentration Highest Level by Area in Fire Station

Type of Pollutant		A	B	C	D
PAH	Naphthalene (㎍/㎥)	3.49	0.85	11.69	0.41
VCM	Chloroethylene (ppm)	N.D	N.D	N.D	N.D
Acid	Hydrogen Chloride (ppm)	0.0183	N.D	N.D	N.D
	Nitric Acid (ppm)	0.0612	0.0167	0.0125	0.0190
	Phosphoric Acid (ppm)	0.0050	0.0023	0.0117	0.0055
	Sulfuric Acid (㎎/㎥)	0.0590	N.D	0.6854	0.0071
Asbestos (f/cc)		0.0015	0.0010	0.0018	0.0012

* N.D : None detection

Table 3-9. Average Concentration Level of CO_2 by Area in Fire Station (Unit: ppm)

Fire Station		Vehicle	Garage	Waiting Room	Office Room 1	Office Room 2
A	Average	738	415	487	***	1,024
	Maximum	2,143	953	668	***	1,339
B	Average	808	***	784	658	605
	Maximum	2,202	***	931	973	979
C	Average	439	***	1,033	1,120	578
	Maximum	496	***	1,205	1,362	794
D	Average	485	***	1,078	528	850
	Maximum	583	***	1,326	816	1,292

* Office Room 1 : Emergency Dispatch Office

** Office Room 2: 119 Center Office Room

*** Device Error

3.5 Discussions

This study evaluated the characteristics of secondary exposure by measuring indoor air quality at four fire fighting offices located in Seoul. Two of them evaluated the indoor space of the fire station and the indoor air quality inside the fire truck within 30 minutes after the firefighters returned home after the fire, and two were evaluated at the usual level. In the meantime, domestic studies have evaluated chemical hazards that are primarily exposed to firefighters, and are limited, and there have been no studies on secondary exposure. Therefore, this study, which conducted the secondary exposure assessment of chemically hazardous substances in the fire department, is a meaningful attempt.

In a study on the risk of exposure to asbestos during firefighting field activities (2010), as a result of analyzing the perception of asbestos harmfulness during firefighting activities through a survey of firefighting officials, 64.3% did not recognize the harmfulness of asbestos. Only about a quarter of firefighting officials recognized that they were exposed to asbestos dust during building collapse and fire suppression, so the importance of firefighting activities through thorough protective equipment was emphasized [37].

In Korea's first study on the characteristics of chemical hazards exposed to fire scenes (2008), acrolein, formaldehyde, benzene, and benzo(a)pyrene, which are harmful factors that firefighters and fire investigation personnel who perform debris cleaning work at 9 building fire scene, may be exposed. Pyrene, aldehydes, VOC, and PAH were identified, and the population-level chart and life expectancy loss of the two groups were evaluated [38]. In the study of hazardous substances exposed to firefighting officials in charge of fire scene, debris cleanup, and fire investigation (2010), it was confirmed that there were hazardous substances exceeding the standards not only in the fire extinguishing stage but also during the fire extinguishing and fire investigation. The importance of wearing respirators was emphasized in order to minimize carcinogenic exposure such as or PAH [39].

Lastly, in a study on the development of management standards for facilities and firefighting equipment to block secondary exposure to harmful factors at the fire station (2013), 15 kinds of carcinogens remaining after the fire test were contaminated with fire protection suits, helmets, and air respirators were identified. And the health factors of the infection control room were identified [40]. In addition, as a result of evaluating the ventilation conditions of the garages of the current firefighting offices, it was confirmed that most of them depend on natural ventilation without separate ventilation facilities, so that the cleaning and storage system of protective equipment such as fire-fighting suits was improved, and the installation standards for garage ventilation facilities and smoke management recommendations were prepared, and the infection control office. It emphasized the implementation of the EO gas sterilizer management guidelines [40]. In the results of this study, particulate matter (PM10) was measured in vehicles and garages relatively higher than in other places.

Michelle et al., as a result of monitoring the concentration of PM10 and PM2.5 in the fire department in downtown Atlanta over three seasons in spring, summer, and autumn, confirmed that PM10 was significantly higher in autumn [42], and Diane Ivy et al. It has been confirmed that PM10 is emitted from diesel emissions when the firefighting equipment is operated [42], and it is estimated that the fine dust (PM10) measured in this study is also due to diesel emissions generated from fire engines or field command vehicles in garages. The exposure standard for PM2.5 was established in January 2015 and has been regulated at an annual average of 25 $\mu g/m^2$ and a 24-hour average of 50 $\mu g/m^2$.

Recently, the Ministry of Environment reinforced the PM 2.5 environmental standard to 35 $\mu g/m^3$ on average per day and 15 $\mu g/m^3$ on annual average through the revision of the 'Enforcement Decree of the Framework Act on Environmental Policy', which has been in force since March 27, 2018. Meanwhile, the Ministry of Environment is presenting the indoor air quality maintenance standards through the enforcement regulations of the Indoor Air Quality Management Act. PM 2.5 items have been newly added to the maintenance standards, and the concentration of 35 $\mu g/m^3$ is not exceeded for medical institutions, day care centers, elderly care facilities, and postpartum care centers. I am not managing it.

For formaldehyde, some of the results measured by Fire Department A were at the US Recommended Exposure Limit Ceiling (80.2% level based on NIOSH REL), and in the PM10 concentration distribution measured at the garage, the second formaldehyde was the highest during the measured period. This is estimated to have been affected by diesel emissions from fire engines. Elliot et al. identified various substances including formaldehyde among harmful substances emitted from vehicles using diesel engines [41, 43, 44].

The concentration level of volatile organic compounds was generally high in Fire Station A, but this is a result of reflecting the rare situation after the fire was extinguished. In addition, most of fire department A exceeded the indoor standard, which is considered to be the effect of returning after fire fighting activities.

Since total volatile organic compounds are also affected by emissions from indoor building materials, it is necessary to identify and manage indoor pollutants that may affect indoor air quality other than firefighting activities. Due to the influence of equipment fuel storage tanks, etc., a relatively high concentration of total volatile organic compounds is being confirmed compared to other places, so chemical management is required.

Since vinyl chloride is highly likely to be generated by decomposition of vinyl chloride contained in polyvinyl chloride (PVC) due to fire, it would be better to review the exposure level at the fire site rather than the indoor environment inside the government building. The concentration of gaseous sulfuric acid measured in the garage of the C Fire Department was 0.6854 ㎎/㎥, which exceeded the exposure standard of the Ministry of Employment and Labor (based on sulfuric acid mist). It is presumed that this is because sulfuric anhydride reacted with moisture to produce sulfuric acid or sulfate. However, since the exposure standards of the Ministry of Employment and Labor can only be applied to sulfuric acid mist, it is impossible to directly compare them, but it is considered meaningful that sulfuric acid was detected at the fire station. Therefore, it was found that the garage needs ventilation facilities to reduce the combustion substances emitted from diesel vehicles, and dangerous chemical substances should be stored in a well-ventilated place and a warning sign should be attached.

According to the「Office air management guidelines」pursuant to Article 27, Paragraph 1 of the Occupational Safety and Health Act, the measurement result of office air quality is evaluated by comparing the average value of the entire measurement value with the management standard for each pollutant, but carbon dioxide is the measurement value measured at each point. They are compared and evaluated based on the maximum value among them. According to the evaluation method according to the office air management guidelines, it was confirmed that in some areas, the average concentration level did not exceed 1,000 ppm, but the maximum value level during the measurement time. Therefore, in order to safely maintain indoor air quality, places where the average or maximum concentration of carbon dioxide exceeds 1,000 ppm require adequate ventilation. Actual firefighters can be exposed to chemically hazardous substances in fire departments for a wide variety of reasons.

At eight fire stations in Portugal, firefighters' occupational secondary exposure to polycyclic aromatic hydrocarbons (PAHs) and urinary toxic substances were monitored at the individual level and the work environment level, respectively, and firefighters exposed to PAHs conducted personal surveillance and bioengineering evaluation. Exposure was also confirmed as a result of performing together [45].

In Oliveria's study, as a result of conducting personal exposure characteristics and risk assessment of polycyclic aromatic hydrocarbons by firefighters at fire departments, the use of fuel, vehicle exhaust gas, and lubricants were identified as the main causes of PAH exposure. This means that even in a fire station environment where no fire has occurred, the level of PAH exposure can affect the health of firefighters [46]. In addition, the research results that PAH collected at the fire site was also found in the lounge and kitchen of the fire station [47] means that it is not much different from the domestic reality in which chemical harmful factors were detected in offices and the like.

In the results of this study, the possibility of contacting harmful factors such as formaldehyde and acids in diesel emissions generated during the start-up inspection, shift inspection, dispatch, and returning stage of fire fighting vehicles was confirmed. Therefore, in order to block harmful substances discharged from vehicles, it is necessary to establish standards for installation of firefighting vehicle smoke gas emission facilities in all fire departments, including fire departments scheduled for new construction or reconstruction, and install and operate the system, and periodic ventilation is required.

The discharge facility is electronically detachable and attachable to the vehicle exhaust, so it is automatically detached when the vehicle moves about 1 m when on the road. In the United States, there are separate standards for designing fire departments and training centers that consider the safety and health of firefighters. In addition, in order to protect firefighters from harmful gases, carbon monoxide detectors are installed in firefighters' lodgings, and a washing machine and laundry space for fire-fighting suits are secured to prevent secondary infection after dispatch [48-50].

In Korea, there are about 15 fire departments operating by installing and operating smoke exhaust systems according to the NFPA standard, and as of the end of December 2017, there are about 15 fire departments, and it is necessary to expand and disseminate them in stages at national fire departments. As a result of evaluating the indoor air quality in a noble situation after the fire scene suppression work, it was confirmed that carbon dioxide, total volatile organic compounds, formaldehyde, and some acids exceeded indoor standards, exposure standards, or related standards. It is necessary to prepare measures for the maintenance of indoor ventilation, the management of some chemical substances, and the management of diesel vehicles and garages.

In a study by the Fire and Disaster Prevention Administration (2013), management standards for facilities and fire fighting equipment have been developed to block secondary exposure to harmful factors [40]. In the future, based on the results of this study, it is necessary to actively and promptly reflect and implement the policy of preparing guidelines for storage of equipment and chemicals in garages in firefighting organizations. It is very important that chemically hazardous substances are exposed directly at the fire scene rather than indirect exposure to the indoor environment. Therefore, it is judged that a systematic monitoring plan is necessary, and this data is considered to be very important in terms of health management of firefighters in the future and management of post data.

In addition, there are many equipments or protective clothing coated in the fire scene, and some fire fighting foams contain a large amount of perfluorinated compounds, so it is expected that firefighters will be exposed to the material. In particular, in the case of perfluorinated compounds, it is believed to be highly likely to cause kidney cancer and scrotum cancer, and is also a substance suspected of causing various other diseases. Therefore, it will be necessary to check the possibility of exposure of firefighters through bio-monitoring and to prepare a plan to manage exposure based on it. It is necessary to build a firefighting vehicle and personal protective equipment (PPE) management system to block harmful factors exposed at the accident scene.

First, the personal protective equipment management system should be settled after returning from the dispatch stage at the accident scene. The problem with the current fire fighting system is that they wear personal protective equipment such as fire fighting protection suits and waterproof boots provided in the pump vehicle to mobilize the fire scene and return to the fire station by boarding a vehicle exposed to harmful substances after the on-scene activity. After activities at the scene exposed to toxic chemicals such as a fire scene, board the firefighting vehicle in that state and return to the fire station. Personal protective equipment is washed with water or a washing machine for fire protection and dried. It is being replaced for dispatch. At this time, there is a possibility that harmful substances buried from the fire scene are exposed to the fire station building and become contaminated. In addition, clothing and equipment exposed to hazardous substances must be manipulated and removed only in designated locations, but there is no system in operation in connection with “isolation” yet.

Second, a personal protective equipment isolation system must be introduced. In order to block the exposure of firefighters to harmful factors, personal protective equipment, etc., should be stored in a separate space. In addition, after on-scene activities, equipment used in a separate container must be collected and returned to the house, and then contaminants must be removed using dedicated cleaning equipment. After that, after drying in a dedicated space, it must be equipped with a system that can be worn and dispatched when dispatched by placing it in a separate compartment for personal equipment. In addition, it should be stipulated to secure a storage room for personal protective equipment in the area dedicated to the government building so that the washed and washed personal protective equipment can be stored in a clean space. Even if personal protective equipment is washed, washed, or disinfected, if it is stored in the rear of the garage where vehicle start-up inspection is performed or in a general warehouse, it is exposed to harmful substances again and is contaminated. It will be mandatory to install by adding the 'area' installation standard.

Lastly, since the standard of decontamination for each dispatch step in Korea has not been established, the situation of eating while wearing firefighting protection suits with pollutants is continuing even during fire fighting. It is necessary to systematically manage and operate emergency fire fighting vehicles and personal protective equipment that are operated unsystemically. In addition, it is necessary to standardize, define and comply with the action procedures that must be performed in the warm zone, transition zone, and cold zone of the fire station's active zone. In this study, A and B were experimental groups, C and D were controls, and some of the 11 measurement items were not measured higher in the experimental group than in the control group. This implies the possibility that the indoor ventilation of the fire department is not smoothly performed. In addition, it means that even in the case of a small fire dispatch rather than an intermediate level fire, the exposure amount is accumulated in the fire department, so that even at the usual level, the level of some harmful substances such as formaldehyde or carbon dioxide can be measured higher than the safe range. This cannot exclude the possibility of the influence of exhaust gas emitted from fire fighting vehicles using diesel engines, as in the study of Eliot et al [43, 44]. Therefore, in the future, firefighters in charge of health and safety will need to take active ventilation measures at each fire station. In addition, the experimental group is a building that was constructed more recently than the control group. Accordingly, considering that facilities such as firefighting facilities and firefighting vehicles are up to date, it can be interpreted that some hazardous substances such as volatile organic compounds and sulfuric acid were measured higher in the control group.

3.6 Limitations and Further study

There were some limitations in carrying out this study. First, the study was conducted by randomly selecting fire departments to be evaluated, but this result cannot be generalized since it was derived from 4 fire departments out of 24 fire departments in Seoul. Therefore, follow-up studies should be carried out so that the results can be representative. Second, it was not possible to evaluate the contribution to how much harmful factors at the fire scene contaminate the interior of the fire station when the same accident occurred. Therefore, in future studies, it is necessary to collect and analyze the first exposure of pollutants in the disaster (fire, etc.) site and the second exposure in the fire station together when dispatching in the same accident. This could be an index to evaluate the degree of diffusion and pollution of pollutants. Third, it was not possible to measure and compare the concentration of air pollutants including the weather in the autonomous district of the Fire Department on the measurement date of the measurement of hazardous substances, and some of the data of the direct reading device was lost.

In the future, it will be possible to more accurately evaluate the degree of influence of secondary chemical exposure through the comparison of indoor air quality in the fire station's indoor space before and after firefighting activities at the fire scene by different research designs in the future, and under conditions unrelated to dispatch. Furthermore, it is necessary to conduct a follow-up study that allows firefighters to evaluate the risk of exposure to chemical hazards and the degree of harm to humans compared to the general population by comparing the air quality in the fire department office compared to general offices.

3.7 Conclusions

In this study, we evaluated indoor air quality in 5 areas of 4 fire departments located in Seoul. Among indoor air pollutants, the concentration levels of carbon dioxide, total volatile organic compounds, and sulfuric acid were above some indoor standards. Total volatile organic compounds were mostly high in garages, and fire department C could reduce airborne concentrations through the management of chemicals such as gasoline. Formaldehyde was high in some garages and interiors. 1,000 ppm of carbon dioxide means that indoor air is stagnant, so it can be solved with periodic ventilation.

Among the combustion-related substances, sulfuric acid, which is a part of the acid, exceeded the exposure standards of the Ministry of Employment and Labor at 0.6854 ppm, but it is judged that it was affected by diesel combustion emissions rather than combustion-related substances. It will be necessary to consider.

In the experimental groups (A,B) compared to the control group (C,D), no more harmful substances were detected in some measurement factors (formaldehyde, sulfuric acid). This has the potential that the accumulation of exhaust gases and chemically hazardous substances from firefighting vehicles, regardless of their returning after dispatch to the disaster scene, not only the indoor air quality but also the health impact of firefighters in the long and short term. Therefore, it supports the need for systematic indoor air quality management at the fire station.

The results of this study can be used to establish the indoor air quality management system of the fire department in the future.

Chapter Ⅳ. The Prevalence of Chronic Disease and Work-related Disease among Korean Firefighters compared with the General Population

4.1 Introduction

Firefighters are repeatedly exposed to unique hazardous environments at the scene of job-related education, training or dispatch in a wide variety of situations [6]. The work environment of firefighters can be divided into three categories: office space, response route of emergency call to scene, and activation scene. The office space includes a waiting room, office, fitness room, restaurant, garage, and fire station rear area. Of these, most of the emergency response routes of call to scene and activation scenes are unpredictable. Therefore, it is highly likely to be exposed to unpredictable risk factors such as various accidents and pollutants.

In particular, it is a very difficult problem to reliably grasp all kinds of harmful substances generated in the process of fire suppression. In the case of Korea, there are not many quantitative measurement data of harmful substances generated during fire suppression, so it is not possible to accurately evaluate what harmful substances actually firefighters are exposed. Actually, the work environment of firefighters is very difficult to measure because the type and degree of exposure of harmful factors differs from scene to scene, unlike general workers. However, according to the Occupational Safety and Health Act, in addition to substances and chemical factors, emergency dispatch and irregular life-related factors are the main causes of health risk.

When materials are burned in the fire scene, they can be exposed to carcinogenic substances and high heat, and working in a posture that is not ergonomic or working face-to-face can lead to various stresses. As a result, they work in an environment with high susceptibility to various diseases such as respiratory disease, cardiovascular disease, cerebrovascular disease, and musculoskeletal disease.

The International Agency for Research Cancer (IARC) defined firefighters' occupational exposure to human carcinogenic potential factor Class 2B, and shift work, which is a biological rhythm disturbing factor, as carcinogenic predictive factor Class 2A. In this way, the firefighter's job characteristics and shift system work doubles the health risk. According to the IARC, it is well known that shift work causes breast cancer by disturbing biological rhythms [14].

According to occupational accidents, it is reported that the risk of occupational accidents increases by up to two times for shift workers including night shifts, such as firefighters [51]. In the case of cardiovascular disease, in a 15-year follow-up study of 504 people, shift workers had a 1.4 times higher risk of cardiovascular disease than those of non-overweight workers, and the risk increased with longer periods [52]. In addition, the risk of myocardial infarction and coronary artery disease increased by 1.31 times and the risk of death from ischemic heart disease was 2.32 times higher in the shift work group and 1.23 times higher in the fixed night work group [53]. In the case of metabolic syndrome, the risk was 1.46 times higher in the shift group. The incidence of metabolic syndrome was 9.0% in the shift work group, which was 5 times more dangerous than 1.8% in the daytime group [54-57].

4.2 Study Objective

The aim of this study was to investigate the prevalence of obesity, hypertension (HTN), diabetes mellitus (DM), metabolic syndrome (MetS), pulmonary ventilation disorder (restrictive, obstructive, combined), noise induced hearing loss (NIHL) among metropolitan firefighters in South Korea. Additionally, we tried to compare these outcomes with general population using data from the Korea National Health and Nutrition Examination Survey (KHANES) in 2018.

4.3 Methods and Materials

4.3.1 Study Design

The design of this study is a cross-sectional study. The analysis was conducted using the results of occupational health examinations for firefighters in metropolitan who were examined at 12 health examination institutions located in Seoul Metropolitan for about 4 months from March 25, 2019 to July 31, 2019. This study was conducted as a firefighter cohort population-based, metropolitan community-based study. In addition, we also had access to data from the Korea National Health and Nutrition Examination Survey, a nation-wide, population-based, cross sectional study conducted by the Korea Centers for Disease Control and Prevention.

4.3.2 Study population

The subject of this study was 7,055 Seoul firefighters working in metropolitan out of 56,639 firefighters nationwide. Of these, 7,024 people were included in this study, excluding 31 patients who did not have a value for the results of special health examinations in the current year (Figure 4-1).

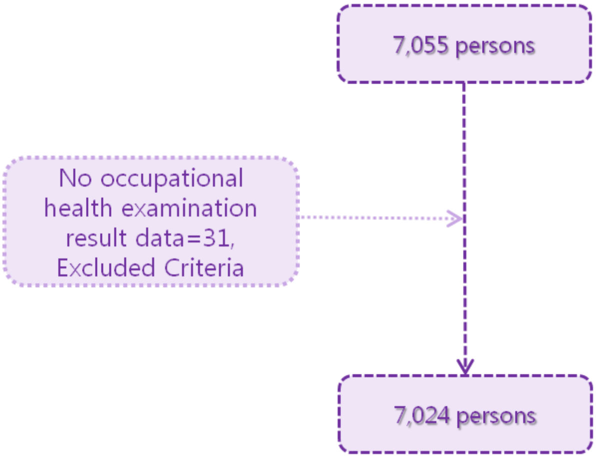


Figure 4-1. Inclusion criteria of firefighter population group

For comparison, we utilized data of general population from the Korea National Health and Nutrition Examination Survey in 2018. Total number of survey participants in 2018 were 7,992. After excluding those who are younger than 20 or older than 60 years old, who are not full-time workers, and those with missing in their work shift, occupation, and all of diseases, there were 1,476 participants in the dataset (Figure 4-2).

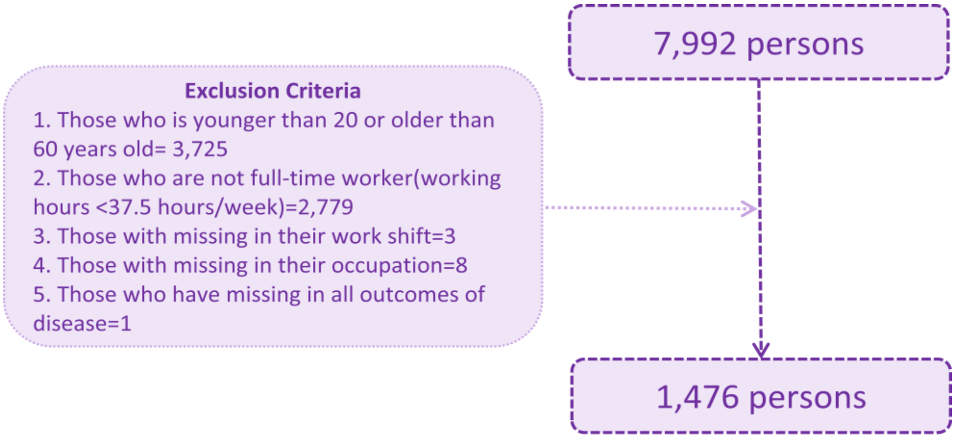


Figure 4-2. Inclusion criteria of general population group

4.3.3 Data source and data collection

We used two data in this study. The first source of data is firefighters' occupational health examination data. The data used in this study are the results of occupational health examinations in 2019 by 7,024 firefighters belonging to the Seoul Metropolitan Fire & Disaster Management Headquarters. In addition, this research data is public data collected and generated by the Seoul Fire & Disaster Headquarters. Firefighters' individual health examination data are computed at each medical institution's health examination center, and the firefighter's health examination DB is established at the Seoul Fire & Disaster Management

Headquarters. At this time, the error in inputting the measured value is minimized by specifying the range of the minimum and maximum values for each variable. This study utilized public data from the results of occupational health examination for firefighters in metropolitan.

The second data source used in this study is public data provided by the Korea Centers for Disease Control and Prevention, and is the result of the 2018 National Health and Nutrition Survey. The survey populations of the National Health and Nutrition Survey extract 192 survey districts annually according to the province, dong, eup, and myeon, and housing type using data from the Population and Housing Census, and select household members within a sample of about 10,000 people. A stratified, multistage probability sampling design was used to produce representative data. Investigations are carried out in two categories: medical checkup, health survey, and nutrition survey.

4.3.4 Variables

We collected data on the 2019 occupational health examination firefighters cohort working in metropolitan. The information collected in this study among the results of occupational health examinations for the firefighters cohort is as follows ; 1) Demographic information (gender, age, total number of years worked, job ranking, job duty position), 2) Physical measurement information (height, weight, waist circumference, systolic blood pressure, diastolic blood pressure, eye vision, hearing function), 3) Clinical Examination Information (Fasting Blood Sugar, Cholesterol, Triglyceride, HDL Cholesterol, LDL Cholesterol, r-GPT, FEV1(%), FVC(%), FEV1/FVC(%), ECG), 4) Health-related information as a result of occupational health examination (diagnosis code classification such as A, C1, C2, D1, D2, ICD-10 code classification). Among the collected demographic information, the job duty position was classified using the current duties such as fire, rescue, emergency medical service (EMS) and others (shift vs non-shift).

In general population, we utilized information Korea National Health and Nutrition Examination Survey in 2018 as follows: 1) Demographic information (gender, age, working hours, job shift, and occupation), 2) physical measurement information (height, weight, waist circumference, systolic blood pressure, diastolic blood pressure), and 3) Clinical Examination information (Fasting Blood Sugar, Cholesterol, Triglyceride, HDL Cholesterol, FEV1(%), FVC(%), FEV1/FVC(%). The hearing function was not measured in 2018, so we used Korea National Health and Nutrition Examination Survey in 2013, which was the most recent measurement.

4.3.5 Outcome measure

The primary outcome was the age- and sex- direct standardized prevalence rates for obesity, hypertension, diabetes mellitus, metabolic syndrome, and pulmonary ventilation disorders, noise induced hearing loss. At this time, in the case of obesity, hypertension, diabetes mellitus and metabolic syndrome, standardized prevalence was calculated for each disease group and pre-disease risk group. Pulmonary ventilation disorders were classified into restrictive, obstructive, and combined, and standardized prevalence was calculated, respectively. The prevalence of noise-induced hearing loss was calculated by the TTA (three tone average) and FTA (four tone average) method, respectively. In addition, the standardized prevalence was calculated based on person-year per 1,000 firefighters.

In addition, obesity, hypertension, diabetes, and metabolic syndrome were divided into disease groups and pre-disease risk groups to calculate indirect standardized prevalence ratio (SPR) for firefighters based on the general population. Pulmonary ventilation disorders were classified into restrictive, obstructive, combined, and standardized prevalence ratio (SPR) was calculated for each. In the case of noise-induced hearing loss, standardized prevalence ratios were calculated for the right and left hearing using the three tone average (TTA) and four tone average (FTA), respectively.

The second result confirmed the general health level of firefighters and the status of diagnosis codes of diseases. In addition, the epidemiologic characteristics of obesity, blood pressure, diabetes mellitus, metabolic syndrome, pulmonary ventilation disorder through lung capacity, general hearing function, noise induced hearing loss and ECG abnormalities were evaluated. Furthermore, the epidemiologic characteristics of firefighters were evaluated by occupational characteristics such as job duty, type of work, total working years of firefighters employed, and occupational health examination classification.

4.3.5.1 BMI and Obesity

Obesity is a condition in which more fat is accumulated than normal. In general, the body mass index is widely used to measure obesity. Body mass index (BMI) is a value obtained by dividing body weight (kg) by the square of height (m^2), and is highly correlated with body fat mass, which is the most used method among indices using weight and height. There is a J-shaped or U-shaped relationship between body mass index and mortality, and the morbidity of obesity-related diseases also increased as the body mass index increased. The classification of the body mass index of Koreans is divided into 6 stages. The classification criteria of the Korean Obesity Society's medical guidelines were applied and analyzed, and the criteria are as follows ;

Underweight is called body mass index less than 18.5, normal is 18.5 to 22.9, and pre-obesity is called overweight or dangerous weight, and is 23 to 24.9. Obesity is again divided into three stages. Stage 1 obesity is 25 to 29.9, stage 2 obesity is 30 to 34.9, and stage 3 obesity is 35 or more.

The primary outcome measure calculates the prevalence of the obesity risk group for the exposure variable, and the secondary outcome measure calculates the prevalence of the obesity group.

4.3.5.2 Hypertension (HTN)

Hypertension is the number one contributor to cardiovascular death [58] and is a strong risk factor affecting ischemic heart disease and stroke (Meta- analysis of 61 prospective, observational studies 1 million adults, 12.7 million person-years) [59]. In addition, hypertension is the most important cause of stroke patients in Korea [60]. It is well known as the most powerful risk factor for stroke.

The criteria for hypertension applied in this study used the revised 6-step classification of the Korean Society of Hypertension in 2019, and the detailed criteria are as follows; Normal blood pressure refers to the optimal blood pressure with the lowest risk of cardio-cerebrovascular disease with a systolic blood pressure of less than 120 mmHg and a diastolic blood pressure of less than 80 mmHg. Attention blood pressure is the systolic blood pressure is 120-129 mmHg, the diastolic blood pressure is less than 80 mmHg. In the pre-hypertensive stage, the systolic blood pressure corresponds to 130-139 mmHg or the diastolic blood pressure is 80-89 mmHg.

Hypertension is classified into two stages. In the first stage of hypertension, the systolic blood pressure is 140-159 mmHg or the diastolic blood pressure is 90-99 mmHg, and the second hypertension is when the systolic blood pressure is 160 mmHg or more or the diastolic blood pressure is 100 mmHg or more. In addition, systolic-only hypertension is when the systolic blood pressure is 140 mmHg or more and the diastolic blood pressure is less than 90 mmHg.

The primary outcome measure calculates the prevalence of the pre-hypertensive group for exposure variables, and the secondary outcome measure calculates the prevalence of the hypertension group.

4.3.5.3 Diabetes Mellitus (DM)

Diabetes was a single factor, and was the third highest contributing mortality rate after high blood pressure and smoking [58]. The criteria for classification of diabetes used in this study were analyzed by the Korean Diabetes Association in 2019 and the National Health and Nutrition Survey. In addition, in this study data, only fasting blood glucose data were used because there was no blood glucose data after 2 hours of oral glucose loading, and the detailed criteria are as follows ;

If the fasting blood sugar was less than 100 mg/dL, it was classified as normal, and if it was 100-125 mg/dL, it was classified as pre-diabetes, a disorder of fasting blood sugar. Finally, if the fasting blood sugar was 126 mg/dL or more, it was classified as diabetes.

The primary outcome measure calculates the prevalence of diabetes risk groups for exposure variables, and the secondary outcome measure calculates the prevalence of diabetes.

4.3.5.4 Metabolic Syndrome (MetS)

Metabolic syndrome is defined as metabolic abnormalities characterized by abdominal obesity, triglyceridemia, high density cholesterol, high blood pressure, glucose intolerance, or diabetes [61]. Metabolic syndrome is a metabolic disorder that raises the risk of chronic diseases by clustering and developing hypertension, hypertension, hyperlipidemia, and abdominal obesity, which are major risk factors for cardiovascular disease. Obesity, hypertension, hypertension, and hyperlipidemia, which are the diagnostic criteria for metabolic syndrome, influence the occurrence of coronary artery disease rather than independently [62].

The diagnostic criteria for metabolic syndrome used in this study refers to the case of receiving more than 3 out of 5 diagnoses as the criteria used in the analysis of the National Health and Nutrition Survey, and the detailed criteria are as follows;

1) Waist circumference : men's 90 cm or more, women's 85 cm or more
2) Blood pressure: 130/85 mmHg or more
3) Triglyceride: 150 mg/dL or more
4) HDL cholesterol: 40 mg/dL or less for men, 50 mg/dL or less for women
5) Fasting blood sugar: Fasting blood sugar 100 mg/dL or more

The primary outcome measure calculates the prevalence of metabolic syndrome risk groups, and the secondary outcome measure calculates the prevalence of metabolic syndrome.

4.3.5.5 Ventilation disorder prevalence and lung function evaluation

Ventilation disorders can be confirmed through lung capacity test results, and are largely classified into three types: restrictive ventilation disorder, obstructive ventilation disorder, and combined (or mixed) ventilation disorder.

First, obstructive ventilation disorder means that the maximum flow rate has decreased compared to the maximum capacity FVC during the effort expiration due to airway obstruction. If FEV1/FVC is less than 0.7 in spirometry results, it is interpreted that there is obstructive ventilation disorder (Figure 4-2). When the obstructive pulmonary disease progresses further and the airway obstruction worsens, a decrease in FEV1 can be observed. Representative diseases include asthma and chronic obstructive pulmonary disease (COPD).

Second, limited ventilation disorder is characterized by decreased TLC and normal FEV1/FVC (Figure 4-2). In spirometry, it can be confirmed that FVC decreases, and FEV1 may decrease secondarily due to a decrease in FVC, but since it remains relatively normal, FEV1/FVC may be normal or slightly increased. Diseases that may exhibit limited ventilation include pulmonary fibrosis, chest wall disease, or neuromuscular disease.

Finally, the combined ventilation disorder is the case of both obstructive and restrictive ventilation disorder, which decreases FEV1/FVC and decreases TLC. In spirometry, FVC can be reduced for both obstructive and restrictive ventilation disorder, so it is necessary to measure TLC to accurately determine whether restrictive ventilation disorder is accompanied (Figure 4-3). Combined ventilation disorders are observed in cases of fibrothorax with airway obstruction due to tuberculosis sequelae, or COPD and pulmonary fibrosis in smokers. It is difficult to distinguish between obstructive and restrictive ventilation disorder in combined ventilation disorders [63].

In this study, the criteria for diagnosing ventilation disorders were used for analysis by applying the criteria recommended by the Korean Respiratory Society.

The primary outcome measure calculated the prevalence of obstructive ventilation disorder for the exposure variable, the secondary outcome measure calculated the prevalence of restrictive ventilation disorder, and the tertiary outcome measure calculated the prevalence of combined ventilation disorder.

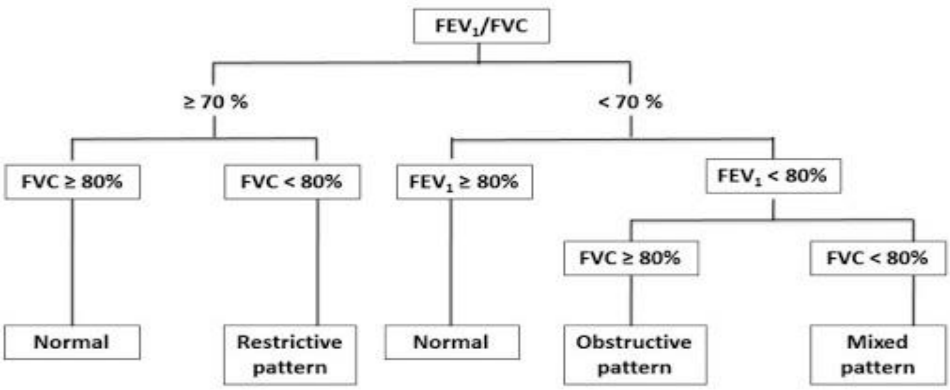


Figure 4-3. Criteria of spirometry assessment in this study

4.3.5.6 Noise-induced Hearing Loss (NIHL)

Noise-induced hearing loss is defined as bilateral sensorineural hearing loss that develops slowly over several years as a result of exposure to continuous or intermittent noise in the workplace. The low frequency side looks normal, but there are cases where a certain frequency falls, which is called noise-induced hearing loss. Noise-induced hearing loss occurs in people working in noisy places, and it drops sharply in the region of 3,000 to 6,000 Hz. In particular, it is well known that it occurs most frequently at 4,000 Hz as a result of pure tone hearing test.

The average hearing threshold is calculated as the airway conduction hearing test threshold. In general, three, four, and six methods are used, and the purpose of obtaining each average value is different, but in general, the third method is used. The noise-induced hearing loss diagnostic criteria used in this study were based on the criteria of C5DIP, 3rd, 4th and 6th.

The primary outcome measure calculates the prevalence of noise-induced hearing loss on the basis of the three tone average method, and the secondary outcome measure calculates the prevalence of noise-induced hearing loss on the basis of the four tone average method.

4.3.5.7 Electrical Cardiogram (ECG)

The electrocardiogram records electrical activity related to the heartbeat as a graphic on the body surface, and 12-lead electrocardiograms of standard guidance, limb lead, and precordial lead are examined. In this study, the number of abnormal waveforms including arrhythmia was calculated except for the normal sinus rhythm.

In this study, the number of abnormal waveforms including arrhythmia was calculated except for the normal sinus rhythm, and the abnormal waveform diagnosis name was also calculated.

4.3.6 Statistical analysis

The distribution of categorical variables are reported as percentages. The continuous variables that were not distributed normally are showed mean and as medians with interquartile ranges.

The age- and sex- adjusted prevalence rates for all of the obesity, hypertension, diabetes mellitus, metabolic syndrome, pulmonary ventilation disorder were calculated using the 2010 census data as the standard population (direct standardization method). The adjusted prevalence rates were calculated according to the obesity, hypertension, diabetes mellitus, metabolic syndrome by disease group and pre-disease group used. The analysis was conducted using SAS ver. 9.4 (SAS Institute, Cary, NC, USA).

The epidemiologic distribution of health status was analyzed for each standard such as working pattern, job duty position, number of firefighter′s working years, and occupational health and disease diagnosis status classification.

occupational health and disease diagnosis status include following ; Height, weight, obesity, hypertension, diabetes mellitus, metabolic syndrome, pure tone hearing function (general hearing loss, noise-induced hearing loss), pulmonary capacity (FEV1(%), FVC(%), FEV1/FVC(%)), pulmonary ventilation disorder (restrictive, obstructive, combined), liver function (r-GPT), electrocardiogram (number of abnormal rhythm diagnoses, type of diagnosis). A chi-square test was performed for group comparison by each criterion.

4.4 Results

4.4.1 Eligible study population

As of December 2019, 56,369 firefighters are working nationwide, and the disease prevalence rate was calculated for 7,024 firefighters in Seoul who received occupational health examinations and had examination results. Prevalence of obesity, hypertension, diabetes, metabolic syndrome, noise-induced hearing loss, pulmonary ventilation disorder according to spirometry results, electrocardiogram results, and abnormal waveform diagnoses including arrhythmia were calculated by dividing them by number (Figure 4-3).

4.4.1.1. Epidemiologic characteristics of Occupational health examinations among firefighters by working pattern

This is the demographic and sociological outcome of 7,024 firefighters in Seoul Metropolitan who received occupational health examinations out of 7,055 in 2019. There were 6,456 (91.9%) males and 568 (8.9%) females, and the average age was 43.5 years (SD 9.5). By age group, 2,450 people (34.9%) were in their 30s. By job duty, fire 3,264 (46.5%), rescue 637 (9.1%), EMS 1,402 (20.0%), administrative and others 1,721 (24.5%). By job position, fire captains who were 6th grade were the most common with 2,360 (33.6%). By the number of working years, 2,485 (35.4%) were in 1~9 years, 2,283 (32.5%) in 20~29 years, and 1,585 (22.6%) in 10-19 years. By classification of general occupation-related disease code, 1,877 (26.7%) healthy people (A), 2,980 (42.4%) people with general diseases (C2), and 1,877 (26.7%) people with occupational diseases (C1). There were 705 (10.0%) patients with general diseases (D2) and 108 patients (1.5%) with occupational diseases (D1). The health conditions classified by the ICD-10 code were 814 (116%) sleep disorders and 749 (10.7%) noise-related disorders (Figure 4-4).

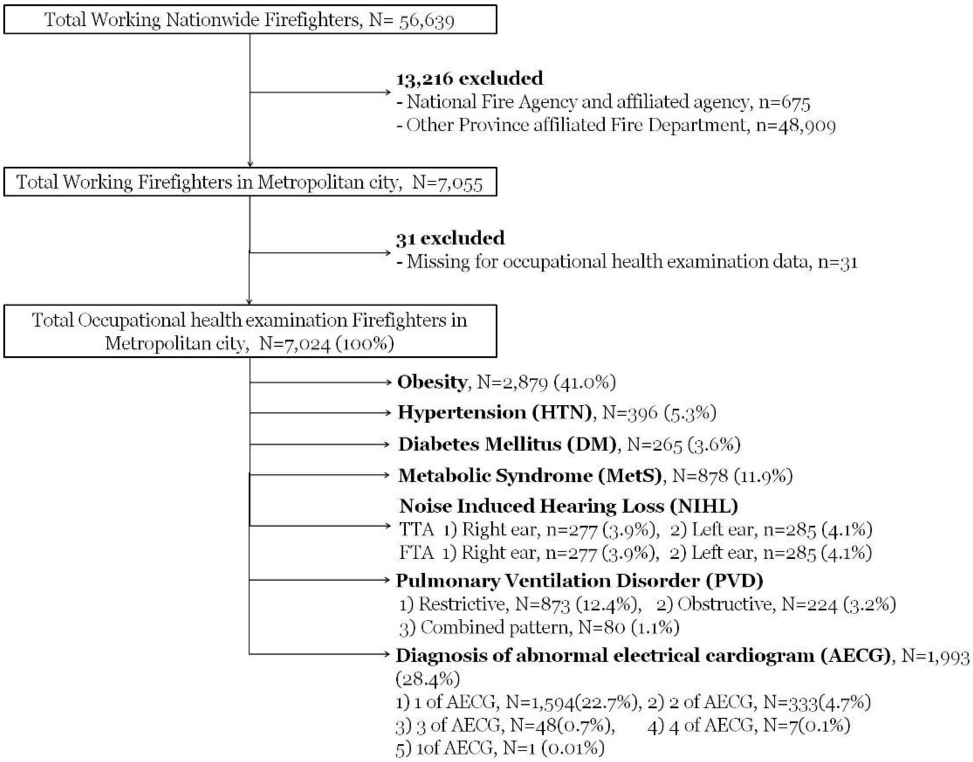


Figure 4-4. Occupational health examinations of working firefighters in Metropolitan

Table 4-1. Demographic Findings by working pattern among Firefighters, in Metropolitan

Potential Risk Factor	Total	Working patterns				P-value
		Shift work		Non-Shift work		
	N (%)	N	%	N	%	
Total	7024 (100.0)	5303		1721		
Gender						<.0001
Male	6456 (91.9)	4975	93.8	1481	86.1	
Female	568 (8.1)	328	6.2	240	13.9	
Age						<.0001
Years, Mean(SD), Median(IQR)	43(9.5), 43(35, 51)	42.3(9.6), 41(34, 50)		45.3(8.8), 46(38, 53)		
20~29	519 (7.4)	473	8.9	46	2.7	
30~39	2450 (34.9)	1956	36.9	494	28.7	
40~49	1951 (27.8)	1402	26.4	549	31.9	
Over 50	2104 (30.0)	1472	27.8	632	36.7	
Job Rank						<.0001
Firefighter	1072 (15.3)	1012	19.1	60	3.5	
Fire engineer	1651 (23.5)	1292	24.4	359	20.9	
Fire lieutenant	1320 (18.8)	975	18.4	345	20.0	
Fire captain	2360 (33.6)	1877	35.4	483	28.1	
Fire marshall	429 (6.1)	122	2.3	307	17.8	
Fire battalion chief	157 (2.2)	24	0.5	133	7.7	
Over Fire assistant chief	35 (0.5)	0	0.0	35	2.0	
Job Duty						<.0001
Fire	3264 (46.5)	3264	61.6	0	0.0	
Rescue	637 (9.1)	637	12.0	0	0.0	
EMS	1402 (20.0)	1402	26.4	0	0.0	
Other	1721 (24.5)	0	0.0	1721	100.0	
Total working experienced year						<.0001
Years, Mean(SD), Median(IQR)	15.3(10.0), 14(6, 24)	18.4(9.5), 19(10, 27)		14.3(9.9), 13(5, 24)		
less than 1	161 (2.3)	159	3.0	2	0.1	
1~9	2485 (35.4)	2062	38.9	423	24.6	
10~19	1585 (22.6)	1139	21.5	446	25.9	

Potential Risk Factor	Total	Working patterns				P-value
		Shift work		Non-Shift work		
	N (%)	N	%	N	%	
20~29	2283 (32.5)	1659	31.3	624	36.3	
Over 30	510 (7.3)	284	5.4	226	13.1	
General Occupational health status						0.009
A	1877 (26.7)	1463	27.6	414	24.1	
C1	1352 (19.2)	984	18.6	368	21.4	
C2	2980 (42.4)	2258	42.6	722	42.0	
D1	108 (1.5)	78	1.5	30	1.7	
D2	705 (10.0)	519	9.8	186	10.8	
General Health status by ICD-10 code						0.38
Sleep disorder	814 (11.6)	598	11.3	216	12.6	
Hypertension	641 (9.1)	468	8.8	173	10.1	
Hyperlipidemia	585 (8.3)	439	8.3	146	8.5	
Diabetes	490 (7.0)	378	7.1	112	6.5	
Heart disease	459 (6.5)	345	6.5	114	6.6	
Rhinitis	458 (6.5)	337	6.4	121	7.0	
Chest related disease	343 (4.9)	241	4.5	102	5.9	
Hemopoietic organ disease	271 (3.9)	212	4.0	59	3.4	
Kidney disease	240 (3.4)	170	3.2	70	4.1	
Liver disease	81 (1.2)	64	1.2	17	1.0	
Ear related disease	91 (1.3)	62	1.2	29	1.7	
Muscular skeletal disease	62 (0.9)	45	0.8	17	1.0	
Obesity	53 (0.7)	42	0.8	11	0.6	
Digestive disease	27 (0.4)	22	0.4	5	0.3	
Breast related disease	4 (0.1)	3	0.1	1	0.1	
Others	51 (0.7)	42	0.8	9	0.5	
Occupational related Health status by ICD-10 code						0.57
Noise related disease	749 (10.7)	571	10.8	178	10.3	
Carbon monoxide related disease	1 (0.01)	1	0.0	0	0.0	

* SD : standard deviation, IQR : interquartile range, ICD : international classification of disease

Table 4-2. Demographic Findings of Occupational Health by Job Current Positions among Firefighters, in Metropolitan

Variables	Total	Job duty positions								P-value
		Fire		Rescue		EMS		Others		
	N (%)	N	%	N	%	N	%	N	%	
Total	7024 (100.0)	3263		637		1402		1722		
Gender										<.0001
Male	6456 (91.9)	3130	95.9	637	100	1207	86.1	1482	86.1	
Female	568 (8.1)	133	4.1	0	0	195	13.9	240	13.9	
Age										<.0001
Years, Mean(SD), Median(IQR)	43(9.5), 43(35,51)	46.2(9.1), 48.0(39,54)		38.3(7.4), 37(33,44)		35.0(6.2), 34(31,38)		45.3(8.8), 46.0(38,53)		
20~29	519 (7.4)	160	4.9	58	9.1	255	18.2	46	2.7	
30~39	2450 (34.9)	730	22.4	353	55.4	873	62.3	494	28.7	
40~49	1951 (27.8)	1001	30.7	176	27.6	225	16.0	549	31.9	
Over 50	2104 (30.0)	1372	42.0	50	7.9	49	3.5	633	36.7	
Job Rank										<.0001
Firefighter	1072 (15.3)	313	9.6	147	8.5	552	39.4	60	3.5	
Fire engineer	1651 (23.5)	509	15.6	230	13.4	553	39.4	359	20.8	
Fire lieutenant	1320 (18.8)	623	19.1	130	7.6	222	15.8	345	20.0	
Fire captain	2360 (33.6)	1694	51.9	108	6.3	75	5.3	483	28.0	
Fire marshall	429 (6.1)	112	3.4	10	0.6	0	0.0	307	17.8	

Variables	Total	Job duty positions								P-value
		Fire		Rescue		EMS		Others		
	N (%)	N	%	N	%	N	%	N	%	
Fire battalion chief	157 (2.2)	12	0.4	12	0.7	0	0.0	133	7.7	
Over Fire assistant chief	35 (0.5)	0	0.0	0	0.0	0	0.0	35	2.0	
Total working experienced year										<.0001
Years, Mean(SD), Median(IQR)	15.3(10.0), 14(6,24)	18.3(9.5), 20.0(10,27)		9.9(7.5), 8.0(4,14)		7.0(6.0), 6.0(3,9)		18.4(9.5), 19.0(10,27)		
less than 1	161 (2.3)	71	1.3	18	1.0	70	5.0	2	0.1	
1~9	2485 (35.4)	715	13.5	360	20.9	987	70.4	423	24.6	
10~19	1585 (22.6)	731	13.8	139	8.1	269	19.2	446	25.9	
20~29	2283 (32.5)	1466	27.6	118	6.9	74	5.3	625	36.3	
Over 30	510 (7.3)	280	5.3	2	0.1	2	0.1	226	13.1	
General Occupational health status										<.0001
A	1877 (26.7)	757	14.3	197	11.4	509	36.3	414	24.0	
C1	1352 (19.2)	714	13.5	161	9.4	108	7.7	369	21.4	
C2	2980 (42.4)	1354	25.5	229	13.3	675	48.1	722	41.9	
D1	108 (1.5)	67	1.3	11	0.6	0	0.0	30	1.7	
D2	705 (10.0)	370	7.0	39	2.3	110	7.8	186	10.8	
General Health status by ICD-10 code										<.0001
Sleep disorder	814 (11.6)	405	12.4	52	8.2	141	10.1	216	12.5	

Variables	Total	Job duty positions								P-value
		Fire		Rescue		EMS		Others		
	N (%)	N	%	N	%	N	%	N	%	
Hypertension	641 (9.1)	336	10.3	40	6.3	92	6.6	173	10.0	
Hyperlipidemia	585 (8.3)	263	8.1	52	8.2	124	8.8	146	8.5	
Diabetes	490 (7.0)	242	7.4	53	8.3	83	5.9	112	6.5	
Heart disease	459 (6.5)	217	6.7	43	6.8	85	6.1	114	6.6	
Rhinitis	458 (6.5)	255	7.8	24	3.8	58	4.1	121	7.0	
Chest related disease	343 (4.9)	166	5.1	23	3.6	52	3.7	102	5.9	
Hemopoietic organ disease	271 (3.9)	111	3.4	27	4.2	74	5.3	59	3.4	
Kidney disease	240 (3.4)	99	3.0	10	1.6	61	4.4	70	4.1	
Liver disease	81 (1.2)	42	1.3	6	0.9	16	1.1	17	1.0	
Ear related disease	91 (1.3)	43	1.3	7	1.1	12	0.9	29	1.7	
Muscular skeletal disease	62 (0.9)	18	0.6	4	0.6	23	1.6	17	1.0	
Obesity	53 (0.7)	24	0.7	5	0.8	13	0.9	11	0.6	
Digestive disease	27 (0.4)	11	0.3	3	0.5	8	0.6	5	0.3	
Breast related disease	4	2	0.1	0	0.0	1	0.1	1	0.1	
others	51 (0.7)	28	0.9	6	0.9	8	0.6	9	0.5	
Occupational related Health status by ICD-10 code										0.43
Noise related disease	749 (10.7)	410	12.6	117	18.4	44	3.1	178	10.3	

Variables	Total	Job duty positions								P-value
		Fire		Rescue		EMS		Others		
	N (%)	N	%	N	%	N	%	N	%	
Carbon monoxide related disease	1	1	0.0	0	0.0	0	0.0	0	0.0	

* SD : standard deviation, IQR : interquartile range, ICD : international classification of disease, EMS : emergency medical service

4.4.1.2. Age- and sex- adjusted standardized prevalence rate by disease group vs risk group

The age- and sex- adjusted direct standardized prevalence rate at disease stage calculated using data from occupational health examination among firefighter results was 35.9% for hypertension (55.1% for males, 15.9% for females) and 1.9% for diabetes (2.9% for males and 0.84% for females), Metabolic syndrome was 12.4% (male 16.9%, female 7.7%), obesity 29.4% (male 41.8%, female 16.5%). In the case of pulmonary ventilation disorder, the restrictive ventilation disorder was 16.8% (male 15.4%, female 18.3%), obstructive ventilation disorder 2.3% (male 4.1%, female 0.4%), and combined ventilation disorder 2.1% (male 1.5%, female 2.5%). In the case of noise-induced hearing loss by the three tone average, the right ear was 2.2% (male 1.8%, female 2.6%), and the left ear was 2.0% (male 1.7%, female 2.3%). In addition, in the case of noise-induced hearing loss by the four tone average, the right ear was 3.2% (male 3.1%, female 3.2%), and the left ear was 3.46% (male 3.3%, female 3.5%).

In addition, the age- and sex- adjusted direct standardized prevalence rate at disease stage calculated using data from National Health and Nutrition Survey of the general population results was 17.9% for hypertension (23.4% for males, 12.1% for females) and 5.3% for diabetes (6.7% for males and 3.8% for females), Metabolic syndrome was 10.5% (male 16.6%, female 4.3%), obesity 34.2% (male 46.9%, female 21.1%). In the case of pulmonary ventilation disorder, the restrictive ventilation disorder was 16.0% (male 18.1%, female 13.9%), obstructive ventilation disorder 4.3% (male 6.1%, female 2.6%), and combined ventilation disorder 1.0% (male 1.8%, female 0.3%). In the case of noise-induced hearing loss by the three tone average, the right ear was 4.4% (male 5.5%, female 3.2%), and the left ear was 4.8% (male 6.4%, female 3.2%). In addition, in the case of noise-induced hearing loss by the four tone average, the right ear was 6.9% (male 8.6%, female 5.2%), and the left ear was 7.96% (male 10.0%, female 5.7%) (Table 4-3, Table 4-5, Figure 4-4, Figure 4-5, Figure 4-6, Figure 4-7).

Furthermore, age- and sex- adjusted direct standardized prevalence rate of the pre-disease among firefighter was 372.6% for hypertension (male 524.4%, female 214.6%), diabetes 23.2% (male 30.8%, female 15.2%), metabolic syndrome 87.2% (male 83.1%, female) 91.5%) and obesity 23.2% (male 33.1%, female 13.0%). In case of general population, age- and sex- adjusted direct standardized prevalence rate of the pre-disease was 25.1% for hypertension (male 33.1%, female 16.9%), diabetes 20.0% (male 25.7%, female 14.1%), metabolic syndrome 40.9% (male 51.4%, female) 30.1%) and obesity 21.7% (male 24.9%, female 18.5%). (Table 4-4, Figure 4-8).

Table 4-3. Age-and sex-adjusted standardized prevalence rate on disease group per 1,000 persons

Disease group	Firefighter				General Population			
	Total	Male (A)	Female (B)	Ratio (A/B)	Total	Male (A)	Female (B)	Ratio (A/B)
Obesity	294.07	418.19	164.95	2.54	342.9	469.36	211.36	2.22
Hypertension (HTN)	35.93	55.15	15.93	3.46	179.25	234.42	121.86	1.92
Diabetes Mellitus (DM)	19.04	29.2	8.46	3.45	53.04	67.47	38.03	1.77
Metabolic Syndrome (MetS)	124.27	169.14	77.59	2.18	105.97	166.12	43.4	3.83
Restrictive ventilation disorder	168.67	154.47	183.21	0.84	160.61	181.41	139.31	1.30
Obstructive ventilation disorder	22.72	41.28	3.71	11.13	43.90	61.27	26.12	2.35
Combined ventilation disorder	20.68	15.62	25.87	0.60	10.76	18.33	3.01	6.08

* Age-and sex-adjusted prevalence per 1,000 persons, using 2010 Korean census statistics

Table 4-4. Age-and sex-adjusted standardized prevalence rate on pre-disease group per 1,000 persons

Risk group	Firefighter				General Population			
	Total	Male (A)	Female (B)	Ratio (A/B)	Total	Male (A)	Female (B)	Ratio (A/B)
Obesity	232.5	330.78	130.26	2.54	217.83	249.12	185.28	1.34
Hypertension (HTN)	372.62	524.46	214.68	2.44	251.8	331.14	169.28	1.96
Diabetes Mellitus (DM)	231.75	307.96	152.46	2.02	200.46	257.28	141.36	1.82
Metabolic Syndrome (MetS)	872.05	830.85	914.91	0.91	409.98	514.47	301.28	1.71

* Age-and sex-adjusted prevalence per 1,000 persons, using 2010 Korean census statistics

Table 4-5. Age-and sex-adjusted standardized prevalence rate on noise-induced hearing loss (NIHL) per 1,000 persons

	Firefighter				General Population			
	Total	Male (A)	Female (B)	Ratio (A/B)	Total	Male (A)	Female (B)	Ratio (A/B)
Right ear by TTA	41.47	33.20	49.93	0.66	44.12	55.08	32.89	1.67
Left ear BY TTA	38.74	31.41	46.23	0.68	48.68	64.10	32.89	1.95
Right ear by FTA	58.76	54.74	62.87	0.87	69.86	86.55	52.76	1.64
Left ear by FTA	63.25	56.36	70.29	0.80	79.15	100.69	57.10	1.76

* TTA : three tone average, FTA : four tone average

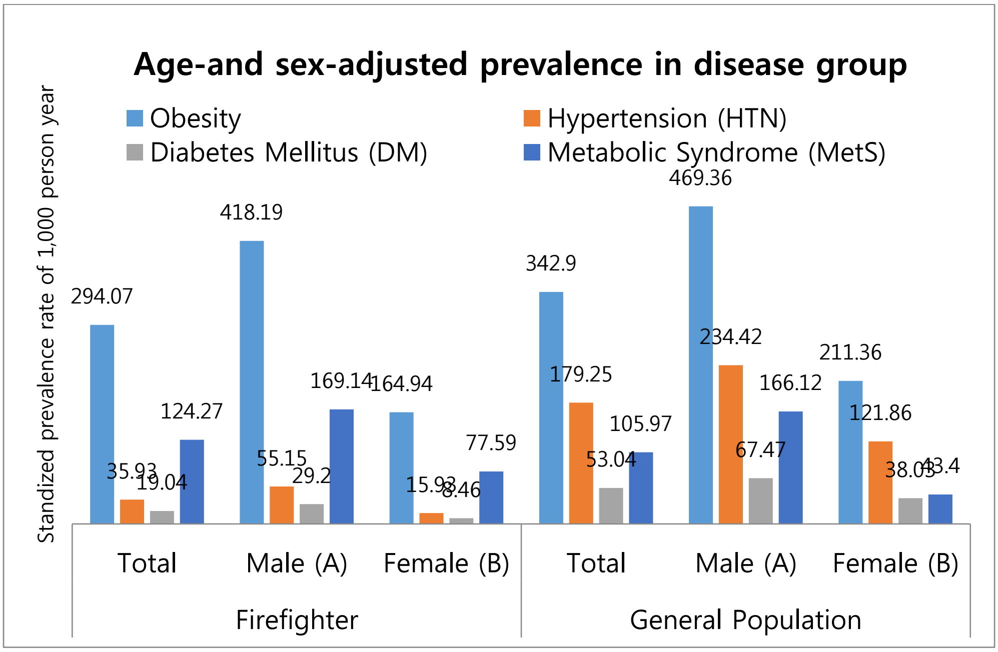


Figure 4-5. Age-and sex-adjusted prevalence on firefighter & general population with chronic disease per 1,000 persons

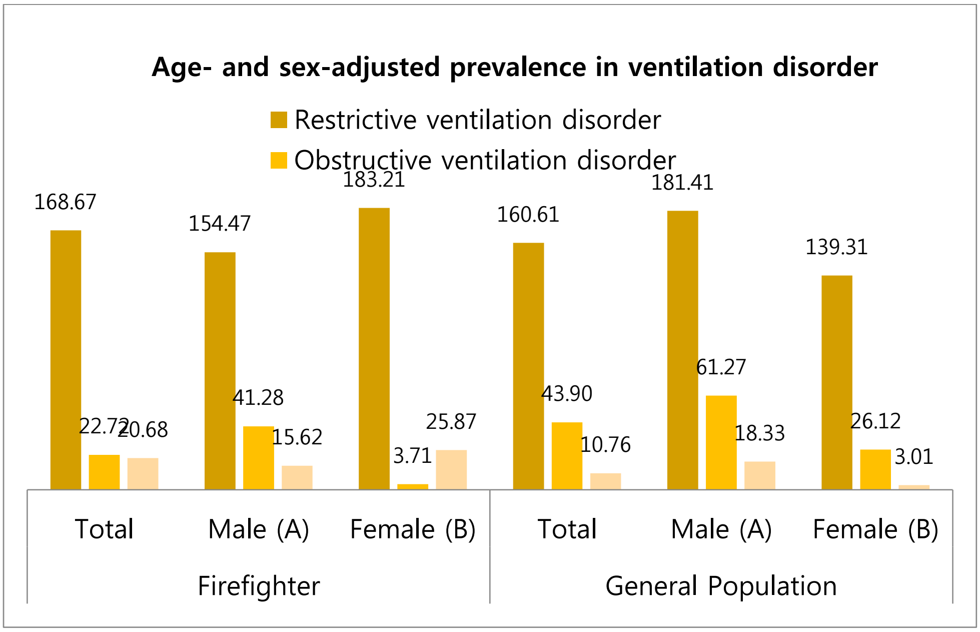


Figure 4-6. Age-and sex-adjusted prevalence on firefighter & general population with pulmonary ventilation disorder per 1,000 persons

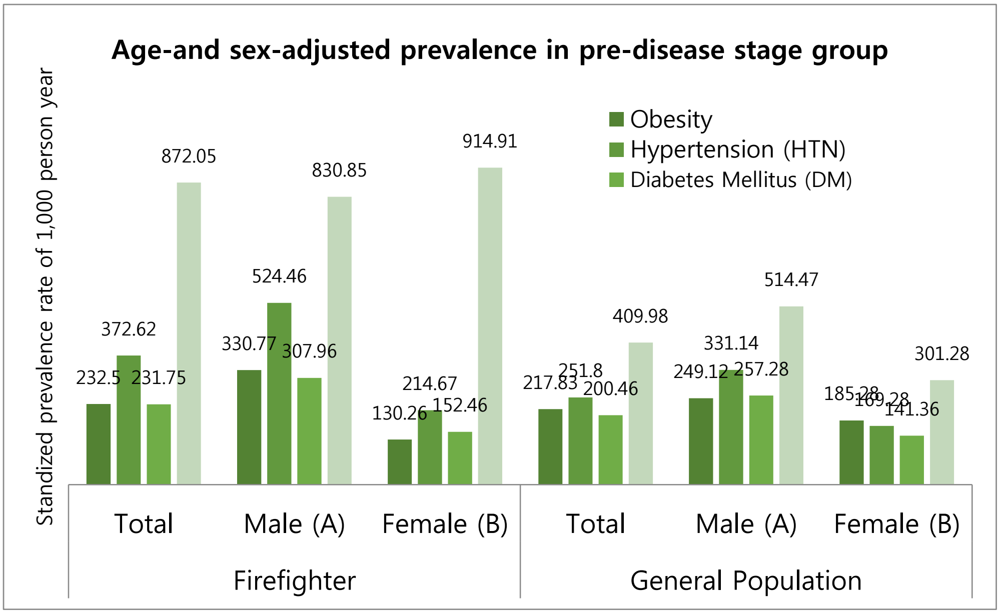


Figure 4-7. Age-and sex-adjusted prevalence on firefighter & general population with pre-disease stage per 1,000 persons

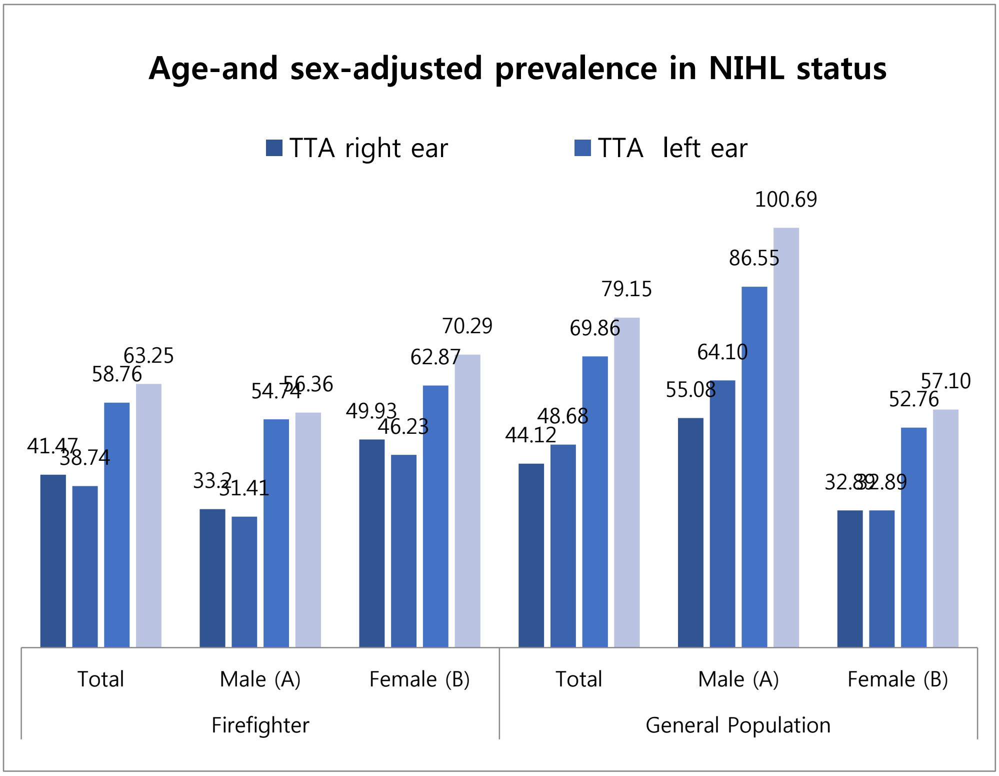


Figure 4-8. Age-and sex-adjusted prevalence on firefighter & general population with NIHL by TTA, FTA per 1,000 persons

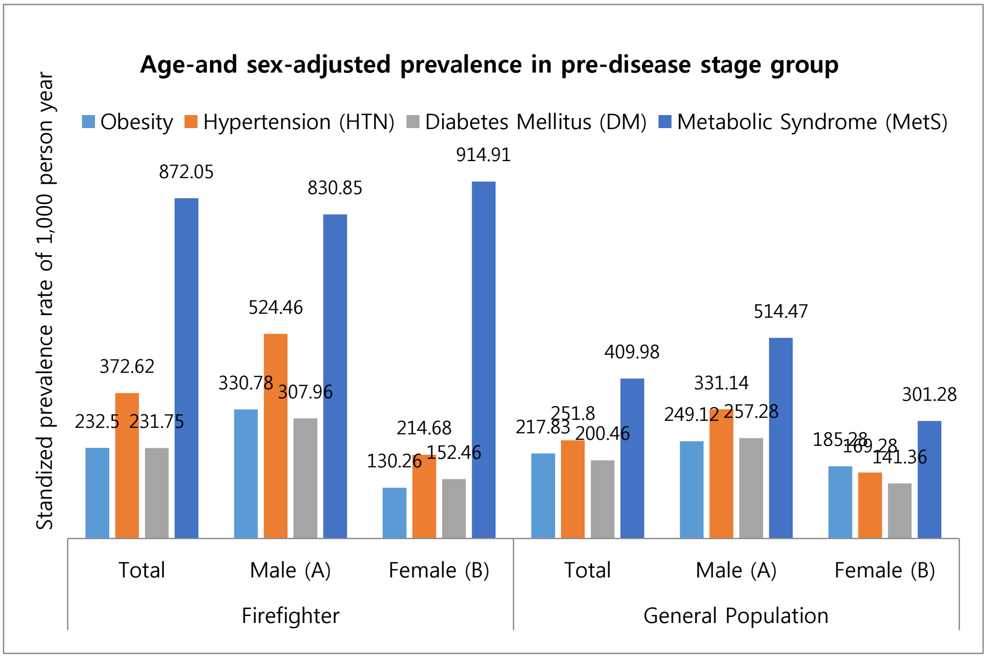


Figure 4-9. Age-and sex-adjusted prevalence on firefighter & general population with pre-disease per 1,000 persons

4.4.1.3. Age- and sex- adjusted indirect standardized prevalence by disease group vs risk group

The standardized prevalence ratio of firefighters and the general population was calculated by dividing into disease group and pre-disease group by age- and sex-adjusted indirect standardization method and analyzed using the general population as the reference group. In the disease group, obesity was 1.12 times (1.08-1.16), hypertension was 0.26 times (0.23-0.28), diabetes was 0.54 times (0.47-0.60), and metabolic syndrome was 1.33 times (1.26-1.40). Restrictive pulmonary ventilation disorder, which is an work-related disease, was 0.95 times (0.88-1.02), and obstructive pulmonary ventilation disorder was 0.25 times (0.21-0.28). Also, in the case of the noise-induced hearing loss by three tone average, the right ear was 0.73 times (0.61-0.85) and the left ear was 0.60 times (0.49-0.69). In the case of the four tone average, both the right and left ears were 0.66 times (0.58-0.74) (Table 4-6).

In the pre-disease group, obesity was 1.34 times (1.29-1.40), hypertension was 1.89 times (1.83-1.96), diabetes mellitus was 1.36 times (1.31-1.41), metabolic syndrome was 1.85 times (1.81-1.90). As above, in the pre-disease group, all diseases had a higher prevalence than the general population (Table 4-7).

Table 4-6. Comparison of disease prevalence between firefighters and the general population with disease stage by indirect standardized prevalence ratio

Disease group	Firefighters Total		GP (reference) Total		Age- and sex-standardized rate		
	N	%	N	%	SPR	95% CI	
Obesity	2,879	41.0	522	36.2	1.12	1.08	1.16
Hypertension (HTN)	396	5.6	294	20.4	0.26	0.23	0.28
Diabetes Mellitus (DM)	265	3.8	87	6.1	0.54	0.47	0.60
Metabolic Syndrome (MetS)	878	12.5	179	12.7	1.33	1.26	1.40

Disease group	Firefighters Total		GP (reference) Total		Age- and sex-standardized rate		
	N	%	N	%	SPR	95% CI	
Restrictive ventilation disorder	873	12.4	118	16.6	0.95	0.88	1.02
Obstructive ventilation disorder	410	5.8	34	4.8	0.25	0.21	0.28
TTA right ear	168	2.4	28	4.6	0.73	0.61	0.85
TTA left ear	159	2.3	31	5.1	0.60	0.49	0.69
FTA right ear	277	3.9	44	7.2	0.66	0.58	0.74
FTA left ear	285	4.1	50	8.2	0.66	0.58	0.74

* GP : general population, TTA : three tone average, FTA : four tone average, SPR : standardized prevalence ratio, CI : confidence interval

Table 4-7. Comparison of disease prevalence between firefighters and the general population with pre-disease stage by standardized prevalence ratio

Risk group	Firefighters Total		GP (reference) Total		Age- and sex- standardized ratio		
	N	%	N	%	SPR	95% CI	
Obesity	2196	31.3	325	22.5	1.34	1.29	1.40
Hypertension (HTN)	2220	31.6	375	26.1	1.89	1.83	1.96
Diabetes Mellitus (DM)	2268	32.3	319	22.4	1.36	1.31	1.41
Metabolic Syndrome (MetS)	3233	46.0	607	42.9	1.85	1.81	1.90

* GP : general population, SPR : standardized prevalence ratio, CI : confidence interval

4.4.1.4. Disease prevalence and potential risk factors

In the health outcomes according to the type of work, among firefighters working in metropolitan, 2196 (31.3%) were overweight and 2,879 (41.1%) were obese. There were 396 patients (5.3%) in the hypertensive group and 3,533 patients (47.7%) in the pre-hypertension group. For both obesity and hypertension, there was no statistical significance between the two groups by shift work type. Diabetes was 265 patients (3.6%), and pre-diabetes was 2,268 patients (30.6%). The diagnostic group for metabolic syndrome was 878 (11.9%), and the risk group for metabolic syndrome was 3,233 (43.7%), and there was statistical significance between the two groups in diabetes mellitus and metabolic syndrome according to shift work (Table 4-8).

General hearing loss tended to increase in both the right and left ears at 2000 Hz, 3000 Hz, and 4000 Hz. In the case of noise-induced hearing loss, there were 168 people on the right (2.4%) and 159 (2.3%) on the left by the three tone average, and 277 (3.9%) on the right and 285 (4.1%) on the left by four tone average method.

Ventilation disorders are classified into restrictive, obstructive, and combined. Of these, restrictive ventilation disorders are divided into three categories. A total of 873 (12.4%) firefighters were included in the restricted ventilation disorder category. Among them, mild was 858 person (12.2%), moderate was 12 person (0.2%), severe was 3 person (0.04%). Obstructive ventilation disorders are classified into 4 categories, a total of 409 person (5.8%) in our data. Among them, mild was 185 person (5.6%) and moderate was 224 (3.2%), and there was no very severe obstruction. Finally, 80 persons (1.1) were diagnosed with combined ventilation disorder (Table 4-8, Table 4-9, Table 4-10, Table 4-11, Table 4-12).

The number of firefighters diagnosed with arrhythmia as a result of electrocardiography varied from 1 to 5 diagnosis per person. As a result of ECG examination, 5,033 patients (71.7%) were read as normal. One abnormal waveform was diagnosed with 1,594 (22.7%), 2 with 333 (4.7%), 3 with 48 (0.7%), 4 with 7 (0.1%), and 5 with 1 (0.01%). The types of abnormal waveforms of arrhythmia varied. There were 1,057 persons (15.1%) of sinus arrhythmia, 339 persons (4.8%) with conduction disorder, 107 persons with abnormal T wave (1.5%), and 106 persons (1.5%) with ventricle hypertrophy.

Table 4-8. Disease prevalence by Working Pattern among Firefighters, in Metropolitan

Potential Risk Factor	Total	Shift work		Non-Shift work		P-value
	N (%)	N	%	N	%	
Total	7024 (100.0)	5303	75.5	1721	24.5	
Height						
Mean(SD), Median(IQR)	172.9(6.1), 173.1(169.2,177.1)	173.3(6.0), 173.4(169.5,177.3)		171.9(6.4), 172.1(168.3,176.3)		
Weight						0.25
BMI, Mean(SD), Median(IQR)	24.5(2.7), 24.4(22.7,26.1)	24.6(2.7), 24.4(22.8,26.2)		24.4(2.8), 24.3(22.6,26)		
Normal	1881 (26.8)	1393	26.3	488	28.4	
Under-weight	68 (1.0)	50	0.9	18	1.0	
Overweight	2196 (31.3)	1656	31.2	540	31.4	
Obesity	2879 (41.0)	2203	41.5	676	39.3	
1st grade	2637 (37.5)	2015	38.0	622	36.1	
2nd grade	233 (3.3)	183	3.5	50	2.9	
3rd grade	9 (1.3)	5	0.1	4	0.2	
Hypertension						0.96
Systolic, Mean(SD), Median(IQR)	121.5(12.1), 121(113,130)	121.7(11.9), 121(113,130)		121.2(12.3), 120(113,130)		
Diastolic, Mean(SD), Median(IQR)	74.4(9.2), 74(68,81)	74.3(9.2), 74(68,80)		74.8(9.3), 75(68,81)		
Normal	3095 (41.8)	2336	44.1	759	44.1	
Pre-hypertension	3533 (47.7)	2667	50.3	866	50.3	
Hypertension	396 (5.3)	299	5.6	97	5.6	
1st grade	245 (3.5)	185	3.5	60	3.5	
2nd grade	11 (0.2)	8	0.2	3	0.2	
Systolic only	140 (2.0)	106	2.0	34	2.0	
Diabetes Mellitus (DM)						0.0005
Glucose level, Mean(SD), Median(IQR)	98.4(16.5), 96(90,103)	97.9(15.8), 96(90,102)		99.9(18.4), 97(91,104)		
Normal	4279 (57.8)	3280	61.9	999	58.0	
Under glucose level	212 (2.9)	174	3.3	38	2.2	
Pre-diabetes	2268 (30.6)	1661	31.3	607	35.3	

Potential Risk Factor	Total	Shift work		Non-Shift work		P-value
	N (%)	N	%	N	%	
Diabetes	265 (3.6)	187	3.5	78	4.5	
Metabolic Syndrome (MetS)						0.0009
Normal	2911 (39.3)	2254	42.5	657	38.2	
Pre-MetS	3233 (43.7)	2420	45.6	813	47.2	
MetS	878 (11.9)	628	11.8	250	14.5	
Pure-tone audiogram						
General hearing loss						
2000Hz						
Right ear	348 (5.0)	253	4.8	95	5.5	0.2
Left ear	401 (5.7)	280	5.3	121	7.0	0.0
3000hz						
Right ear	607 (8.6)	437	8.2	170	9.9	0.0
Left ear	686 (9.8)	515	9.7	171	9.9	0.8
4000hz						
Right ear	1052 (15.0)	763	14.4	289	16.8	0.0
Left ear	1129 (16.1)	830	15.7	299	17.4	0.1
Noise Induced Hearing Loss (NIHL)						
C5DIP	1672 (22.6)	1227	23.1	445	25.9	
Right ear	822 (11.1)	633	11.9	217	12.6	0.0
Left ear	850 (11.5)	594	11.2	228	13.2	0.5
Three tone average	327 (4.7)	1166	22.0	476	27.7	
Right ear	168 (2.4)	230	4.3	97	2.6	0.1
Left ear	159 (2.3)	112	2.1	47	2.7	0.1
Four tone agerage	562 (8.0)	395	7.4	167	9.7	
Right ear	277 (3.9)	197	3.7	80	4.6	
Left ear	285 (4.1)	198	3.7	87	5.1	0.0
Six tone average	1 (0.01)	1	0.02	0	0.0	
Right ear	1 (0.01)	1	0.02	0	0.0	
Left ear	0	0	0.0	0	0.0	

Potential Risk Factor	Total	Shift work		Non-Shift work		P-value
	N (%)	N	%	N	%	
Simple spirometry						
FEV1(%)						
Mean(SD), Median(IQR)	88.5(13.4), 88.4(81.4, 95.4)	88.7(14.1), 88.8(82.0, 95.6)		87.7(10.9), 88.0(80.9, 95)		<.0001
FVC(%)						
Mean(SD), Median(IQR)	90.6(10.4), 90.6(84.0, 97.4)	90.9(10.3), 91.0(84.0, 97.9)		89.8(10.4), 89.6(83.0, 97)		0.0008
FEV1/FVC(%)						
Mean(SD), Median(IQR)	79.6(12.7), 79.8(75.6, 83.8)	79.6(6.9), 80.0(75.7, 83.9)		79.7(22.6), 79.2(75.2, 83.3)		0.01
Restrictive	6535 (90.2)	4937	93.1	1598	92.9	0.0006
Normal	5662 (80.6)	4319	81.4	1343	78.0	
Mild	858 (12.2)	608	11.5	250	14.5	
Moderate	12 (0.2)	8	0.2	4	0.2	
Severe	3 (0.04)	2	0.0	1	0.1	
Obstructive	409 (5.8)	308	5.8	101	5.9	0.3
Mild	185 (2.6)	144	2.7	41	2.4	
Moderate	224 (3.2)	164	3.1	60	3.5	
Combined pattern	80 (1.1)	57	1.1	23	1.3	
Liver function						
r-Gpt						0.01
Mean(SD) Median(IQR)	36.6(36.6), 26.0(18, 41)	35.9(36.5), 25.0(18, 40)		38.7(36.8), 28.0(18, 44)		
Low	1 (0.01)	0	0.0	1	0.1	
Normal	6144 (87.4)	4670	88.1	1474	85.6	
Abnormal	878 (12.5)	631	11.9	247	14.4	
1st risk	545 (7.8)	387	7.3	158	9.2	
2nd risk	211 (3.0)	160	3.0	51	3.0	
3rd risk	122 (1.7)	84	1.6	38	2.2	
No. of Diagnosis number of abnormal Electrocardiogram (ECG)						0.01
Normal	5031 (71.7)	3752	70.8	1279	74.3	
1	1594 (22.7)	1242	23.4	352	20.5	
2	333 (4.7)	261	4.9	72	4.2	
3	48 (0.7)	36	0.7	12	0.7	
4	7 (0.1)	4	0.1	3	0.2	

Potential Risk Factor	Total	Shift work		Non-Shift work		P-value
	N (%)	N	%	N	%	
5	1 (0.01)	1	0.0	0	0.0	
Type of diagnosis	7016	5297	99.9	1719	99.9	0.0007
Normal	5033 (71.7)	3754	70.9	1279	74.4	
Ischemic heart disease	39 (0.6)	29	0.5	10	0.6	
PR interval disorder	33 (0.5)	21	0.4	12	0.7	
OT interval disorder	27 (0.4)	22	0.4	5	0.3	
Abnormal Q wave	35 (0.5)	26	0.5	9	0.5	
Abnormal R wave	19 (0.3)	13	0.2	6	0.3	
Abnormal T wave	107 (1.5)	68	1.3	39	2.3	
ST segment change	79 (1.1)	58	1.1	21	1.2	
WPW	10 (0.1)	7	0.1	3	0.2	
Sinus Arrhythmia	1057 (15.1)	844	15.9	213	12.4	
Atrial Arrythmia	33 (0.5)	29	0.5	4	0.2	
Ventricle Arrythmia	59 (0.8)	52	1.0	7	0.4	
Atrium Hypertrophy	3	2	0.0	1	0.1	
Ventricle Hypertrophy	106 (1.5)	81	1.5	25	1.5	
Right Axis deviation	37 (0.5)	30	0.6	7	0.4	
Conduction disorder	339 (4.8)	261	4.9	78	4.5	

* SD : standard deviation, IQR : interquartile range, WPW : Wolff-Parkinson-White syndrome

Table 4-9. Disease prevalence by Job Duty Position among Firefighters, in Metropolitan

Potential Risk Factor	Total	Job duty position								P-value
		Fire		Rescue		EMS		Other		
	N (%)	N	%	N	%	N	%	N	%	
Total	7024	3263	100	637	100	1402	100	1722	100	
Height										
Mean(SD) Median(IQR)	172.9(6.1) 173.1(169.2,177.1)	172.8(5.7) 172.8(168.9,176.6)		175.1(4.9) 174.8(171.6,178.4)		173.4(6.9), 173.9(169.7,178.1)		171.9(6.4) 172.1(168.3,176.3)		
Weight										<.0001
BMI, Mean(SD) Median(IQR)	24.5(2.7) 24.4(22.7, 26.1)	24.7(2.7) 24.5(22.9, 26.3)		24.9(2.4) 24.8(23.3, 26.2)		24.2(2.8) 24.1(22.5, 25.8)		24.4(2.8) 24.3(22.6, 26)		
Normal	1881 (26.8)	819	25.1	124	19.5	450	32.1	488	28.3	
Under-weight	68 (1.0)	30	0.9	2	0.3	18	1.3	18	1.0	
Overweight	2196 (31.3)	1020	31.3	213	33.4	423	30.2	540	31.4	
Obesity	2879 (41.0)	1394	42.7	298	46.8	511	36.4	676	39.3	
1st grade	2637 (37.5)	1279	39.2	278	43.6	458	32.7	622	36.1	
2nd grade	233 (3.3)	111	3.4	20	3.1	52	3.7	50	2.9	
3rd grade	9 (1.3)	4	0.1	0	0.0	1	0.1	4	0.2	
Hypertension										<.0001
Systolic Mean(SD), Median(IQR)	121.5(12.1) 121(113, 130)	122.2(12.3) 121(114, 131)		122.0(11.2) 121(115, 130)		120.3(11.6) 120(112, 128)		121.1(12.3) 120(113, 130)		
Diastolic, Mean(SD), Median(IQR)	74.4(9.2), 74(68, 81)	75.2(9.3), 75(68, 82)		73.6(8.9), 73(67, 80)		72.6(8.7), 72(66, 78)		74.8(9.3), 75(68, 81)		
Normal	3095 (41.8)	1408	43.2	268	42.1	660	47.1	759	44.1	

Potential Risk Factor	Total	Job duty position								P-value
		Fire		Rescue		EMS		Other		
	N (%)	N	%	N	%	N	%	N	%	
Pre-hypertension	3533 (47.7)	1627	49.9	343	53.8	697	49.7	866	50.3	
Hypertension	396 (5.3)	228	7.0	26	4.1	45	3.2	97	5.6	
1st grade	245 (3.5)	135	4.1	14	2.2	36	2.6	60	3.5	
2nd grade	11 (0.2)	7	0.2	0	0.0	1	0.1	3	0.2	
Systolic only	140 (2.0)	86	2.6	12	1.9	8	0.6	34	2.0	
Diabetes Mellitus (DM)										<.0001
Glucose level Mean(SD), Median(IQR)	98.4(16.5), 96(90, 103)	100.1(17.8), 97(91, 104)		96.5(13.8), 95(89, 101)		93.6(9.5), 93(88, 99)		99.8(18.3), 97(91, 104)		
Normal	4279 (57.8)	1845	56.5	420	65.9	1015	72.4	999	58.0	
Under glucose level	212 (2.9)	86	2.6	21	3.3	67	4.8	38	2.2	
Pre-diabetes	2268 (30.6)	1174	36.0	179	28.1	308	22.0	607	35.2	
Diabetes	265 (3.6)	158	4.8	17	2.7	12	0.9	78	4.5	
Metabolic Syndrome (MetS)										<.0001
Normal	2911 (39.3)	1153	35.3	317	49.8	784	55.9	657	38.2	
Pre-MetS	3233 (43.7)	1627	49.9	274	43.0	519	37.0	813	47.2	
MetS	878 (11.9)	483	14.8	46	7.2	99	7.1	250	14.5	
Pure-tone audiogram										
General hearing tone loss										
2000Hz										
Right ear	348 (5.0)	212	6.5	31	4.9	10	0.7	95	5.5	<.0001
Left ear	401 (5.7)	232	7.1	36	5.7	12	0.9	121	7.0	<.0001

Potential Risk Factor	Total	Job duty position								P-value
		Fire		Rescue		EMS		Other		
	N (%)	N	%	N	%	N	%	N	%	
3000hz										
Right ear	607 (8.6)	347	10.6	69	10.8	21	1.5	170	9.9	<.0001
Left ear	686 (9.8)	394	12.1	93	14.6	28	2.0	171	9.9	<.0001
4000hz										
Right ear	1052 (15.0)	585	17.9	129	20.3	49	3.5	289	16.8	<.0001
Left ear	1129 (16.1)	628	19.2	140	22.0	62	4.4	299	17.4	<.0001
Noise Induced Hearing Loss (NIHL)										
C5DIP	1672 (22.6)	931	28.5	226	35.5	70	5.0	445	25.8	
Right ear	822 (11.1)	455	13.9	110	17.3	29	2.1	228	13.2	<.0001
Left ear	850 (11.5)	476	14.6	116	18.2	41	2.9	217	12.6	<.0001
Three tone average	327 (4.7)	196	6.0	21	3.3	13	0.9	97	5.6	
Right ear	168 (2.4)	102	3.1	9	1.4	7	0.5	50	2.9	<.0001
Left ear	159 (2.3)	94	2.9	12	1.9	6	0.4	47	2.7	<.0001
Four tone average	562 (8.0)	326	10.0	36	5.7	33	2.4	167	9.7	
Right ear	277 (3.9)	162	5.0	18	2.8	17	1.2	80	4.6	<.0001
Left ear	285 (4.1)	164	5.0	18	2.8	16	1.1	87	5.1	<.0001
Six tone average	1 (0.01)	1	0.03	0	0.0	0	0.0	0	0.0	
Right ear	1 (0.01)	1	0.03	0	0.0	0	0.0	0	0.0	
Left ear	0	0	0.0	0	0.0	0	0.0	0	0.0	
Simple spirometry										

Potential Risk Factor	Total	Job duty position								P-value
		Fire		Rescue		EMS		Other		
	N (%)	N	%	N	%	N	%	N	%	
FEV1(%)										
Mean(SD) Median(IQR)	88.5(13.4) 88.4(81.4, 95.4)	87.9(16.0) 87.8(80.7, 95.0)		90.5(9.7) 90.2(84.6, 97.0)		89.9(10.2) 90.0(83.1, 96.9)		87.7(10.9) 88.0(80.9, 95.0)		0.0001
FVC(%)										
Mean(SD) Median(IQR)	90.6(10.4) 90.6(84.0, 97.4)	89.8(10.4) 89.9(83.0, 97.0)		93.7(9.4) 93.0(87.1, 100.0)		92.0(10.0) 92.0(86.0, 98.1)		89.7(10.3) 89.6(83.0, 97.0)		0.0005
FEV1/FVC(%)										
Mean(SD) Median(IQR)	79.6(12.7) 79.8(75.6, 83.8)	78.6(6.9) 78.9(74.7, 82.7)		79.8(6.3) 80.1(76.0, 83.8)		81.9(6.7) 82.0(78.0, 86.0)		79.7(22.6) 79.2(75.2, 83.3)		<.0001
Restrictive	6535 (90.2)	2985	91.5	598	93.9	1354	96.6	1598	92.8	<.0001
Normal	5662 (80.6)	2519	77.2	566	88.9	1234	88.0	1343	78.0	
Mild	858 (12.2)	460	14.1	32	5.0	116	8.3	250	14.5	
Moderate	12 (0.2)	5	0.2	0	0.0	3	0.2	4	0.2	
Severe	3 (0.04)	1	0.0	0	0.0	1	0.1	1	0.1	
Obstructive	409 (5.8)	230	7.0	37	5.8	41	2.9	101	5.9	0.04
Mild	185 (2.6)	113	3.5	19	3.0	12	0.9	41	2.4	
Moderate	224 (3.2)	117	3.6	18	2.8	29	2.1	60	3.5	
Combined pattern	80 (1.1)	48	1.5	7	1.1	2	0.1	23	1.3	
Liver function										
r-Gpt										<.0001
Mean(SD) Median(IQR)	36.6(36.6) 26.0(18.0, 41.0)	38.8(38.7) 27.0(19.0, 44.0)		34.0(29.1) 24.0(18.0, 37.0)		30.1(33.4) 21.0(15.0, 32.0)		38.7(36.8) 28.0(18.0, 44.0)		

Potential Risk Factor	Total	Job duty position								P-value
		Fire		Rescue		EMS		Other		
	N (%)	N	%	N	%	N	%	N	%	
Low	1 (0.01)	0	0.0	0	0.0	0	0.0	1	0.1	
Normal	6144 (87.4)	2818	86.4	565	88.7	1287	91.8	1474	85.6	
Abnormal	878 (12.5)	445	13.6	72	11.3	114	8.1	247	14.3	
1st risk	545 (7.8)	267	8.2	49	7.7	71	5.1	158	9.2	
2nd risk	211 (3.0)	118	3.6	14	2.2	28	2.0	51	3.0	
3rd risk	122 (1.7)	60	1.8	9	1.4	15	1.1	38	2.2	
No. of Diagnosis number of abnormal Electrocardiogram (ECG)										0.01
Normal	5031 (71.7)	2316	71.0	411	64.5	1025	73.1	1279	74.3	
1	1594 (22.7)	762	23.4	181	28.4	299	21.3	352	20.4	
2	333 (4.7)	155	4.8	40	6.3	66	4.7	72	4.2	
3	48 (0.7)	24	0.7	3	0.5	9	0.6	12	0.7	
4	7 (0.1)	3	0.1	0	0.0	1	0.1	3	0.2	
5	1 (0.01)	1	0.0	0	0.0	0	0.0	0	0.0	
Type of diagnosis	7016	3260		637		1400		1719		<.0001
Normal	5033 (71.7)	2317	71.1	411	64.5	1026	73.3	1279	74.4	
Ischemic heart disease	39 (0.6)	19	0.6	2	0.3	6	0.4	12	0.7	
PR interval disorder	33 (0.5)	16	0.5	1	0.2	4	0.3	12	0.7	
OT interval disorder	27 (0.4)	15	0.5	2	0.3	5	0.4	5	0.3	
Abnormal Q wave	35 (0.5)	18	0.6	4	0.6	4	0.3	9	0.5	
Abnormal R wave	19 (0.3)	7	0.2	1	0.2	5	0.4	6	0.3	

Potential Risk Factor	Total	Job duty position								P-value
		Fire		Rescue		EMS		Other		
	N (%)	N	%	N	%	N	%	N	%	
Abnormal T wave	107 (1.5)	44	1.3	13	2.0	11	0.8	39	2.3	
ST segment change	79 (1.1)	41	1.3	7	1.1	10	0.7	21	1.2	
WPW	10 (0.1)	6	0.2	0	0.0	1	0.1	3	0.2	
Sinus Arrhythmia	1057 (15.1)	500	15.3	130	20.4	214	15.3	213	12.4	
Atrial Arrythmia	33 (0.5)	19	0.6	6	0.9	4	0.3	4	0.2	
Ventricle Arrythmia	59 (0.8)	35	1.1	8	1.3	9	0.6	7	0.4	
Atrium Hypertrophy	3	2	0.1	0	0.0	0	0.0	1	0.1	
Ventricle Hypertrophy	106 (1.5)	51	1.6	8	1.3	22	1.6	25	1.5	
Right Axis deviation	37 (0.5)	13	0.4	7	1.1	10	0.7	7	0.4	
Conduction disorder	339 (4.8)	157	4.8	35	5.5	69	4.9	78	4.5	

* SD : standard deviation, IQR : interquartile range, WPW : Wolff-Parkinson-White syndrome, EMS : emergency medical service

Table 4-10. Disease prevalence by Gender among Firefighters, in Metropolitan

Potential Risk Factor	Total	Gender				P-value
		Male		Female		
	N (%)	N	%	N	%	
Total	7024 (100.0)	6456		568		
Height						
Mean(SD) Median(IQR)	172.9(6.1), 173.1(169.2,177.1)	173.9(5.2), 173.6(170.1,177.5)		162.1(4.8), 162(158.6,165.3)		
Weight						<.0001
BMI, Mean(SD), Median(IQR)	24.5(2.7), 24.4(22.7, 26.1)	24.7(2.6), 24.6(23.0, 26.3)		21.8(2.7), 21.4(19.9, 23.2)		
Normal	1881 (26.8)	1508	23.4	373	65.7	
Under-weight	68 (1.0)	26	0.4	42	7.4	
Overweight	2196 (31.3)	2121	32.9	75	13.2	
Obesity	2879 (41.0)	2801	43.4	78	13.7	
1st grade	2637 (37.5)	2568	39.8	69	12.1	
2nd grade	233 (3.3)	224	3.5	9	1.6	
3rd grade	9 (1.3)	9	0.1	0	0.0	
Hypertension						<.0001
Systolic, Mean(SD), Median(IQR)	121.5(12.1), 121(113,130)	122.5(11.6), 122.0(115,130)		110.4(10.9), 109(103,117)		
Diastolic, Mean(SD), Median(IQR)	74.4(9.2), 74(68,81)	75(9.1), 75(68,81)		67.9(8.1), 67(62,72)		
Normal	3095 (41.8)	2641	40.9	454	79.9	
Pre-hypertension	3533 (47.7)	3427	53.1	106	18.7	
Hypertension	396 (5.3)	388	6.0	8	1.4	
1st grade	245 (3.5)	240	3.7	5	0.9	
2nd grade	11 (0.2)	11	0.2	0	0.0	
Systolic only	140 (2.0)	137	2.1	3	0.5	
Diabetes Mellitus (DM)						<.0001
Glucose level, Mean(SD), Median(IQR)	98.4(16.5), 96(90,103)	99.1(16.9), 97(91,103)		91(8.6), 90(85,96)		
Normal	4279 (57.8)	3836	59.4	443	78.0	
Under glucose level	212 (2.9)	167	2.6	45	7.9	
Pre-diabetes	2268 (30.6)	2191	33.9	77	13.6	
Diabetes	265 (3.6)	262	4.1	3	0.5	<.0001

Potential Risk Factor	Total	Gender				P-value
		Male		Female		
	N (%)	N	%	N	%	
Metabolic Syndrome (MetS)						
Normal	2911 (39.3)	2494	38.6	417	73.4	
Pre-MetS	3233 (43.7)	3099	48.0	134	23.6	
MetS	878 (11.9)	863	13.4	15	2.6	
Pure-tone audiogram						
General hearing loss						
2000Hz						
Right ear	348 (5.0)	341	5.3	7	1.2	<.0001
Left ear	401 (5.7)	394	6.1	7	1.2	<.0001
3000hz						
Right ear	607 (8.6)	602	9.3	5	0.9	<.0001
Left ear	686 (9.8)	681	10.5	5	0.9	<.0001
4000hz						
Right ear	1052 (15.0)	1046	16.2	6	1.1	<.0001
Left ear	1129 (16.1)	1124	17.4	5	0.9	<.0001
Noise Induced Hearing Loss (NIHL)						
C5DIP						
Right ear	822 (11.1)	819	12.7	3	0.5	<.0001
Left ear	850 (11.5)	846	13.1	4	0.7	<.0001
Three tone average						
Right ear	168 (2.4)	161	2.5	7	1.2	<.0001
Left ear	159 (2.3)	153	2.4	6	1.1	0.039
Four tone average						
Right ear	277 (3.9)	269	4.2	8	1.4	0.0004
Left ear	285 (4.1)	275	4.3	10	1.8	0.0025
Six tone average						
Right ear	1 (0.01)	1	0.02	0	0.0	
Left ear	0	0	0.0	0	0.0	
Simple spirometry						
FEV1(%)						

Potential Risk Factor	Total	Gender				P-value
		Male		Female		
	N (%)	N	%	N	%	
Mean(SD), Median(IQR)	88.5(13.4), 88.4(81.4,95.4)	88.4(13.5), 88.2(81.3,95.3)		88.9(11.6), 89.2(82,96)		
FVC(%)						
Mean(SD), Median(IQR)	90.6(10.4), 90.6(84,97.4)	90.5(10.3), 90.5(84,97.4)		90.9(10.9), 91(85, 98)		
FEV1/FVC(%)						
Mean(SD), Median(IQR)	79.6(12.7), 79.8(75.6,83.8)	79.3(13), 79.1(75.1,83)		83.4(8.3), 83.9(80,87.4)		
Restrictive	6535 (90.2)	5980		555		0.0002
Normal	5662 (80.6)	5173	80.1	489	86.1	
Mild	858 (12.2)	797	12.3	61	10.7	
Moderate	12 (0.2)	8	0.1	4	0.7	
Severe	3 (0.04)	2	0.0	1	0.2	
Obstructive	409 (5.8)	403	6.2	7	1.2	0.22
Mild	185 (2.6)	184	2.9	1	0.2	
Moderate	224 (3.2)	219	3.4	6	1.1	
Combined pattern	80 (1.1)	73	1.1	7	1.2	
Liver function						
r-Gpt						<.0001
Mean(SD), Median(IQR)	36.6(36.6), 26(18,41)	38.3(37.5), 27.0(19,43)		16.5(11.5), 14(11,18)		
Low	1 (0.01)	0	0.0	1	0.2	
Normal	6144 (87.4)	5594	86.6	550	96.8	
Abnormal	878 (12.5)	864	13.4	17	3.0	
1st risk	545 (7.8)	530	8.2	15	2.6	
2nd risk	211 (3.0)	210	3.3	1	0.2	
3rd risk	122 (1.7)	121	1.9	1	0.2	
No. of Diagnosis of Electrocardiogram (ECG)		6452		562		
Normal	5031 (71.7)	4571	70.8	460	81.0	
1	1594 (22.7)	1514	23.5	80	14.1	
2	333 (4.7)	316	4.9	17	3.0	
3	48 (0.7)	43	0.7	5	0.9	
4	7 (0.1)	7	0.1	0	0.0	
5	1 (0.01)	1	0.0	0	0.0	

Potential Risk Factor	Total	Gender				P-value
		Male		Female		
	N (%)	N	%	N	%	
Type of diagnosis	7016	6454		562		<.0001
Normal	5033 (71.7)	4573	70.9	460	81.9	
Ischemic heart disease	39 (0.6)	37	0.6	2	0.4	
PR interval disorder	33 (0.5)	27	0.4	6	1.1	
OT interval disorder	27 (0.4)	23	0.4	4	0.7	
Abnormal Q wave	35 (0.5)	35	0.5	0	0.0	
Abnormal R wave	19 (0.3)	12	0.2	7	1.2	
Abnormal T wave	107 (1.5)	105	1.6	2	0.4	
ST segment change	79 (1.1)	78	1.2	1	0.2	
WPW	10 (0.1)	9	0.1	1	0.2	
Sinus Arrhythmia	1057 (15.1)	1005	15.6	52	9.3	
Atrial Arrythmia	33 (0.5)	32	0.5	1	0.2	
Ventricle Arrythmia	59 (0.8)	56	0.9	3	0.5	
Atrium Hypertrophy	3	3	0.0	0	0.0	
Ventricle Hypertrophy	106 (1.5)	104	1.6	2	0.4	
Right Axis deviation	37 (0.5)	30	0.5	7	1.2	
Conduction disorder	339 (4.8)	325	5.0	14	2.5	

* SD : standard deviation, IQR : interquartile range, WPW : Wolff-Parkinson-White syndrome

Table 4-11. Disease prevalence by Occupational Disease Diagnosis Status among Firefighters, in Metropolitan

Potential Risk Factor	Total	Occupational disease diagnosis status										P-value
		A		C1		C2		D1		D2		
	N (%)	N	%	N	%	N	%	N	%	N	%	
Total	7024 (100.0)	1877		1352		2980		108		705		
Height												
Mean(SD), Median(IQR)	172.9(6.1), 173.1(169.2,177.1)	173.4(6.4), 173.8(169.5,177.7)		172.7(5.2), 172.4(169.2,176)		172.8(6.4), 173.2(169.1,177.2)		172.4(4.7), 171.8(169.1,174.9)		172.6(5.7), 172.7(168.9,176.4)		
Weight												<.0001
BMI, Mean(SD), Median(IQR)	24.5(2.7), 24.4(22.7,26.1)	23.9(2.4), 23.8(22.4,25.3)		24.7(2.6), 24.7(23.2,26.3)		24.6(2.8), 24.5(22.7,26.3)		25.3(2.6), 25.2(23.7,26.8)		25.3(2.9), 25.1(23.5,27)		
Normal	1881 (26.8)	633	33.7	288	21.3	804	27.0	20	18.5	136	19.3	
Under-weight	68 (1.0)	19	1.0	10	0.7	35	1.2	0	0.0	4	0.6	
Overweight	2196 (31.3)	636	33.9	439	32.5	893	30.0	27	25.0	201	28.5	
Obesity	2879 (41.0)	589	31.4	615	45.5	1248	41.9	61	56.5	364	51.6	
1st grade	2637 (37.5)	558	29.7	571	42.2	1132	38.0	58	53.7	316	44.8	
2nd grade	233 (3.3)	30	1.6	44	3.3	110	3.7	3	2.8	46	6.5	
3rd grade	9 (1.3)	1	0.1	0	0.0	6	0.2	0	0.0	2	0.3	
Hypertension												<.0001
Systolic, Mean(SD), Median(IQR)	121.5(12.1), 121(113,130)	119.5(10.6), 119(112,127)		122.1(11.6), 121(114,130)		121.2(12), 120(113,130)		124.4(12.3), 125(116.5, 133)		126.7(14.5), 126(117,135)		
Diastolic, Mean(SD), Median(IQR)	74.4(9.2), 74(68,81)	72.2(8), 72(66,78)		75.4(8.9), 75(69,82)		74.3(9.1), 74(68,81)		77.2(8.9), 77(70.5, 84)		78.9(11.1), 78(71, 86)		

Potential Risk Factor	Total	Occupational disease diagnosis status										P-value
		A		C1		C2		D1		D2		
	N (%)	N	%	N	%	N	%	N	%	N	%	
Normal	3095 (41.8)	916	48.8	566	41.9	1347	45.2	36	33.3	230	32.6	
Pre-hypertension	3533 (47.7)	958	51.0	707	52.3	1480	49.7	62	57.4	324	46.0	
Hypertension	396 (5.3)	3	0.2	79	5.8	153	5.1	10	9.3	151	21.4	
1st grade	245 (3.5)	3	0.2	44	3.3	117	3.9	7	6.5	74	10.5	
2nd grade	11 (0.2)	0	0.0	3	0.2	3	0.1	0	0.0	5	0.7	
Systolic only	140 (2.0)	0	0.0	32	2.4	33	1.1	3	2.8	72	10.2	
Diabetes Mellitus (DM)												<.0001
Glucose level, Mean(SD), Median(IQR)	98.4(16.5), 96(90,103)	93.7(8.1), 93(88,98)		102.5(19.3), 99(92,107)		97.0(11.5), 96(90,103)		103.9(23.3), 100(93,106)		108.3(31.2), 100(92,111)		
Normal	4279 (57.8)	1442	76.8	696	51.5	1761	59.1	51	47.2	327	46.4	
Under glucose level	212 (2.9)	59	3.1	31	2.3	110	3.7	0	0.0	12	1.7	
Pre-diabetes	2268 (30.6)	376	20.0	516	38.2	1059	35.5	50	46.3	267	37.9	
Diabetes	265 (3.6)	0	0.0	109	8.1	50	1.7	7	6.5	99	14.0	
Metabolic Syndrome (MetS)												<.0001
Normal	2911 (39.3)	1171	62.4	425	31.4	1130	37.9	27	25.0	158	22.4	
Pre-MetS	3233 (43.7)	650	34.6	705	52.1	1460	49.0	57	52.8	359	50.9	
MetS	878 (11.9)	56	3.0	222	16.4	388	13.0	24	22.2	188	26.7	
Pure-tone audiogram												
General hearing loss												

Potential Risk Factor	Total	Occupational disease diagnosis status										P-value
		A		C1		C2		D1		D2		
	N (%)	N	%	N	%	N	%	N	%	N	%	
2000Hz												
Right ear	348 (5.0)	2	0.1	184	13.6	31	1.0	87	80.6	44	6.2	<.0001
Left ear	401 (5.7)	2	0.1	217	16.1	37	1.2	90	83.3	55	7.8	<.0001
3000hz												
Right ear	607 (8.6)	0	0.0	453	33.5	20	0.7	93	86.1	41	5.8	<.0001
Left ear	686 (9.8)	4	0.2	516	38.2	20	0.7	92	85.2	54	7.7	<.0001
4000hz												
Right ear	1052 (15.0)	0	0.0	861	63.7	35	1.2	103	95.4	53	7.5	<.0001
Left ear	1129 (16.1)	0	0.0	934	69.1	32	1.1	100	92.6	63	8.9	<.0001
Noise Induced Hearing Loss (NIHL)												
C5DIP												
Right ear	822 (11.1)	0	0.0	662	49.0	21	0.7	95	88.0	44	6.2	<.0001
Left ear	850 (11.5)	0	0.0	688	50.9	12	0.4	97	89.8	53	7.5	<.0001
Three tone average												
Right ear	168 (2.4)	1	0.1	27	2.0	18	0.6	83	76.9	39	5.5	<.0001
Left ear	159 (2.3)	2	0.1	22	1.6	15	0.5	72	66.7	48	6.8	<.0001
Four tone average												
Right ear	277 (3.9)	16	0.9	79	5.8	43	1.4	87	80.6	52	7.4	<.0001

Potential Risk Factor	Total	Occupational disease diagnosis status										P-value
		A		C1		C2		D1		D2		
	N (%)	N	%	N	%	N	%	N	%	N	%	
Left ear	285 (4.1)	12	0.6	86	6.4	45	1.5	85	78.7	57	8.1	<.0001
Six tone average												
Right ear	1 (0.01)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.14	
Left ear	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	
Simple spirometry												
FEV1(%)												
Mean(SD), Median(IQR)	88.5(13.4), 88.4(81.4,95.4)	91.9(8.8), 91.3(85.7,97.8)		87.9(11.3), 88(80.9,95)		87.2(16.4), 87(79.7,94.2)		84.5(11.5), 84.6(78,91)		86.1(11.4), 86.2(79,94)		
FVC(%)												
Mean(SD), Median(IQR)	90.6(10.4), 90.6(84,97.4)	94.2(8.3), 93.3(88,99.1)		89.9(10.6), 89.7(83,97)		89.5(10.6), 89.6(82,97)		86.3(10.5), 85.9(80,93)		87.5(11), 87.7(80.9,94.2)		
FEV1/FVC(%)												
Mean(SD), Median(IQR)	79.6(12.7), 79.8(75.6,83.8)	80.8(5.5), 80.9(77,84)		77.7(6.6), 78(74, 82)		79.8(7.3), 80(75.9,84.2)		75.9(5.5), 76.0(73,79)		79.9(34.6), 78.9(74.9,82.8)		
Restrictive	6535 (90.2)											
Normal	5662 (80.6)	1867	99.5	1047	77.4	2169	72.8	71	65.7	507	71.9	<.0001
Mild	858 (12.2)	1	0.1	172	12.7	531	17.8	22	20.4	132	18.7	
Moderate	12 (0.2)	0	0.0	3	0.2	5	0.2	0	0.0	4	0.6	
Severe	3 (0.04)	0	0.0	0	0.0	2	0.1	0	0.0	1	0.1	
Obstructive	409 (5.8)											

Potential Risk Factor	Total	Occupational disease diagnosis status										P-value
		A		C1		C2		D1		D2		
	N (%)	N	%	N	%	N	%	N	%	N	%	
Mild	185 (2.6)	7	0.4	55	4.1	104	3.5	3	2.8	15	2.1	0.001
Moderate	224 (3.2)	0	0.0	47	3.5	134	4.5	8	7.4	35	5.0	
Combined pattern	80 (1.1)	2	0.1	28	2.1	35	1.2	4	3.7	11	1.6	
Liver function												
r-Gpt												<.0001
Mean(SD), Median(IQR)	36.6(36.6), 26(18,41)	27.0(20.7), 21(15,31)		40.5(33.6), 29.5(21,48)		36.1(35.8), 25(18,41)		47.7(53.3), 32(22,53)		54.9(59.8), 35(23,62)		
Low	1 (0.01)	0	0.0	0	0.0	1	0.0	0	0.0	0	0.0	
Normal	6144 (87.4)	1786	95.2	1135	83.9	2603	87.3	88	81.5	530	75.2	
Abnormal	878 (12.5)	90	4.8	217	16.1	376	12.6	20	18.5	175	24.8	
1st risk	545 (7.8)	63	3.4	149	11.0	238	8.0	9	8.3	86	12.2	
2nd risk	211 (3.0)	19	1.0	47	3.5	96	3.2	7	6.5	42	6.0	
3rd risk	122 (1.7)	8	0.4	21	1.6	42	1.4	4	3.7	47	6.7	
No. of Diagnosis of Electrocardiogram (ECG)												
Normal	5031 (71.7)	1425	75.9	974	72.0	2016	67.7	72	66.7	543	77.0	<.0001
1	1594 (22.7)	393	20.9	293	21.7	753	25.3	26	24.1	128	18.2	
2	333 (4.7)	54	2.9	70	5.2	171	5.7	6	5.6	32	4.5	
3	48 (0.7)	1	0.1	10	0.7	31	1.0	4	3.7	2	0.3	
4	7 (0.1)	0	0.0	2	0.1	5	0.2	0	0.0	0	0.0	

Potential Risk Factor	Total	Occupational disease diagnosis status										P-value
		A		C1		C2		D1		D2		
	N (%)	N	%	N	%	N	%	N	%	N	%	
5	1 (0.01)	0	0.0	0	0.0	1	0.0	0	0.0	0	0.0	
Type of diagnosis	7016											
Normal	5033 (71.7)	1425	75.9	974	72.0	2017	67.7	72	66.7	544	77.2	<.0001
Ischemic heart disease	39 (0.6)	1	0.1	9	0.7	24	0.8	0	0.0	5	0.7	
PR interval disorder	33 (0.5)	2	0.1	5	0.4	22	0.7	2	1.9	2	0.3	
OT interval disorder	27 (0.4)	2	0.1	6	0.4	15	0.5	1	0.9	3	0.4	
Abnormal Q wave	35 (0.5)	0	0.0	5	0.4	23	0.8	2	1.9	5	0.7	
Abnormal R wave	19 (0.3)	5	0.3	4	0.3	8	0.3	0	0.0	2	0.3	
Abnormal T wave	107 (1.5)	5	0.3	25	1.8	64	2.1	3	2.8	10	1.4	
ST segment change	79 (1.1)	5	0.3	12	0.9	47	1.6	3	2.8	12	1.7	
WPW	10 (0.1)	0	0.0	4	0.3	5	0.2	0	0.0	1	0.1	
Sinus Arrhythmia	1057 (15.1)	321	17.1	181	13.4	459	15.4	19	17.6	77	10.9	
Atrial Arrythmia	33 (0.5)	0	0.0	14	1.0	17	0.6	0	0.0	2	0.3	
Ventricle Arrythmia	59 (0.8)	9	0.5	6	0.4	40	1.3	0	0.0	4	0.6	
Atrium Hypertrophy	3	0	0.0	1	0.1	1	0.0	0	0.0	1	0.1	
Ventricle Hypertrophy	106 (1.5)	14	0.7	20	1.5	60	2.0	2	1.9	9	1.3	
Right Axis deviation	37 (0.5)	15	0.8	2	0.1	19	0.6	0	0.0	1	0.1	
Conduction disorder	339 (4.8)	70	3.7	83	6.1	155	5.2	4	3.7	27	3.8	

* SD : standard deviation, IQR : interquartile range, WPW : Wolff-Parkinson-White syndrome

Table 4-12. Disease prevalence by number of years worked as a firefighter

Potential Risk Factor	Total	Number of years worked as a firefighter										P-value
		Less than 1 year		1~9 years		10~19 years		20~29 years		Over 30 years		
	N (%)	N	%	N	%	N	%	N	%	N	%	
Total	7024 (100.0)	161		2485		1585		2283		510		
Height												
Mean(SD), Median(IQR)	172.9(6.1), 173.1(169.2,177.1)	174.1(6.8), 175.3(169.9,178.6)		174.4(6.5), 174.8(170.8,178.8)		172.6(6.5), 173.2(168.8,177.2)		171.9(5.1), 171.8(168.5,175.1)		171.0(4.8), 171.0(167.9,174.1)		
Weight												<.0001
BMI, Mean(SD), Median(IQR)	24.5(2.7), 24.4(22.7,26.1)	23.5(2.4), 23.4(22,24.9)		24.3(2.7), 24.3(22.6,26)		24.4(2.7), 24.3(22.7,26.2)		24.7(2.6), 24.6(23,26.3)		24.7(2.5), 24.7(23,26.2)		
Normal	1881 (26.8)	68	42.2	712	28.7	438	27.6	545	23.9	118	23.1	
Under-weight	68 (1.0)	1	0.6	35	1.4	16	1.0	12	0.5	4	0.8	
Overweight	2196 (31.3)	53	32.9	790	31.8	496	31.3	708	31.0	149	29.2	
Obesity	2879 (41.0)	39	24.2	948	38.1	635	40.1	1018	44.6	239	46.9	
1st grade	2637 (37.5)	35	21.7	856	34.4	582	36.7	936	41.0	228	44.7	
2nd grade	233 (3.3)	4	2.5	88	3.5	53	3.3	78	3.4	10	2.0	
3rd grade	9 (1.3)	0	0.0	4	0.2	0	0.0	4	0.2	1	0.2	
Hypertension												<.0001
Systolic, Mean(SD), Median(IQR)	121.5(12.1), 121(113,130)	120.5(11.3), 120(112,127)		120.3(11.6), 119(113,129)		121.1(11.8), 120(113,130)		122.6(12.2), 122(114,131)		123.6(13.1), 124(115,133)		
Diastolic, Mean(SD),	74.4(9.2),	71.8(8.4),		72.2(8.6),		74.6(9.3),		76.4(9.3),		76.4(8.9),		

Potential Risk Factor	Total	Number of years worked as a firefighter										P-value
		Less than 1 year		1~9 years		10~19 years		20~29 years		Over 30 years		
	N (%)	N	%	N	%	N	%	N	%	N	%	
Median(IQR)	74(68,81)	72(66,77)		72(66,78)		74(68,81)		76(70,83)		76(70,83)		
Normal	3095 (41.8)	75	46.6	1197	48.2	706	44.5	924	40.5	193	37.8	
Pre-hypertension	3533 (47.7)	79	49.1	1203	48.4	802	50.6	1178	51.6	271	53.1	
Hypertension	396 (5.3)	7	4.3	85	3.4	77	4.9	181	7.9	46	9.0	
1st grade	245 (3.5)	7	4.3	62	2.5	42	2.6	102	4.5	32	6.3	
2nd grade	11 (0.2)	0	0.0	2	0.1	2	0.1	6	0.3	1	0.2	
Systolic only	140 (2.0)	0	0.0	21	0.8	33	2.1	73	3.2	13	2.5	
Diabetes Mellitus (DM)												<.0001
Glucose level, Mean(SD), Median(IQR)	98.4(16.5), 96(90,103)	91.4(9.0), 91(86,96)		93.3(10.6), 93(88,98)		92.2(12.7), 96(90,102)		103.1(19.8), 100(93,107)		107.6(24.3), 101.5(95,112)		
Normal	4279 (57.8)	128	79.5	1852	74.5	995	62.8	1096	48.0	208	40.8	
Under glucose level	212 (2.9)	11	6.8	115	4.6	42	2.6	41	1.8	3	0.6	
Pre-diabetes	2268 (30.6)	21	13.0	505	20.3	515	32.5	993	43.5	234	45.9	
Diabetes	265 (3.6)	1	0.6	13	0.5	33	2.1	153	6.7	65	12.7	
Metabolic Syndrome (MetS)												<.0001
Normal	2911 (39.3)	126	78.3	1413	56.9	649	40.9	604	26.5	119	23.3	
Pre-MetS	3233 (43.7)	32	19.9	922	37.1	746	47.1	1253	54.9	280	54.9	
MetS	878 (11.9)	3	1.9	149	6.0	190	12.0	425	18.6	111	21.8	
Pure-tone audiogram												

Potential Risk Factor	Total	Number of years worked as a firefighter										P-value
		Less than 1 year		1~9 years		10~19 years		20~29 years		Over 30 years		
	N (%)	N	%	N	%	N	%	N	%	N	%	
General hearing loss												
2000Hz												
Right ear	348 (5.0)	0	0.0	16	0.6	37	2.3	214	9.4	81	15.9	<.0001
Left ear	401 (5.7)	1	0.6	27	1.1	31	2.0	245	10.7	97	19.0	<.0001
3000hz												
Right ear	607 (8.6)	0	0.0	42	1.7	80	5.0	375	16.4	110	21.6	<.0001
Left ear	686 (9.8)	1	0.6	63	2.5	77	4.9	406	17.8	139	27.3	<.0001
4000hz												
Right ear	1052 (15.0)	3	1.9	88	3.5	150	9.5	634	27.8	177	34.7	<.0001
Left ear	1129 (16.1)	3	1.9	124	5.0	172	10.9	639	28.0	191	37.5	<.0001
Noise Induced Hearing Loss (NIHL)												
C5DIP												
Right ear	822 (11.1)	2	1.2	63	2.5	122	7.7	498	21.8	137	26.9	<.0001
Left ear	850 (11.5)	3	1.9	91	3.7	118	7.4	497	21.8	141	27.6	<.0001
Three tone average												
Right ear	168 (2.4)	0	0.0	7	0.3	14	0.9	102	4.5	45	8.8	<.0001
Left ear	159 (2.3)	0	0.0	8	0.3	11	0.7	93	4.1	47	9.2	<.0001

Potential Risk Factor	Total	Number of years worked as a firefighter										P-value
		Less than 1 year		1~9 years		10~19 years		20~29 years		Over 30 years		
	N (%)	N	%	N	%	N	%	N	%	N	%	
Four tone average												
Right ear	277 (3.9)	0	0.0	17	0.7	27	1.7	163	7.1	70	13.7	<.0001
Left ear	285 (4.1)	1	0.6	19	0.8	25	1.6	168	7.4	72	14.1	<.0001
Six tone average												
Right ear	1 (0.01)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	
Left ear	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	
Simple spirometry												
FEV1(%)												
Mean(SD), Median(IQR)	88.5(13.4), 88.4(81.4,95.4)	90.8(9.5), 90.9(85.5,97.3)		90.6(16.6), 90.2(84,97)		88.3(10.3), 88(81.3,95)		86.7(11.2), 87(79.7,94)		85.6(12.3), 85.6(78,94.8)		
FVC(%)												
Mean(SD), Median(IQR)	90.6(10.4), 90.6(84,97.4)	93(9.7), 93(87.7,99.4)		92.6(9.5), 92.3(86.8,99)		90.9(10.1), 90.4(84,97.8)		88.8(10.8), 89(82,96)		86.7(10.8), 86.3(79.6,94)		
FEV1/FVC(%)												
Mean(SD), Median(IQR)	79.6(12.7), 79.8(75.6,83.8)	83.6(7.0), 84(79.3,88)		81.9(6.3), 82(78.2,86)		80.4(23.3), 80(76.5,83.6)		77.1(6.5), 77.2(73.5,81)		75.6(6.8), 76(71.8,80)		
Restrictive	6535 (90.2)											<.0001
Normal	5662 (80.6)	146	90.7	2244	90.3	1317	83.1	1643	72.0	312	61.2	
Mild	858 (12.2)	11	6.8	171	6.9	182	11.5	386	16.9	108	21.2	

Potential Risk Factor	Total	Number of years worked as a firefighter										P-value
		Less than 1 year		1~9 years		10~19 years		20~29 years		Over 30 years		
	N (%)	N	%	N	%	N	%	N	%	N	%	
Moderate	12 (0.2)	0	0.0	3	0.1	2	0.1	5	0.2	2	0.4	
Severe	3 (0.04)	0	0.0	0	0.0	1	0.1	2	0.1	0	0.0	
Obstructive	409 (5.8)											0.19
Mild	185 (2.6)	1	0.6	22	0.9	30	1.9	104	4.6	28	5.5	
Moderate	224 (3.2)	3	1.9	34	1.4	46	2.9	104	4.6	37	7.3	
Combined pattern	80 (1.1)	0	0.0	11	0.4	7	0.4	39	1.7	23	4.5	
Liver function												
r-Gpt												<.0001
Mean(SD), Median(IQR)	36.6(36.6), 26(18,41)	22.8(12.7), 19(15,25)		28.9(26.6), 21(16,32)		36.9(40.2), 26(17,42)		43.8(41.3), 31(21,50)		44.8(40.7), 30(22,51)		
Low	1 (0.01)	0	0.0	0	0.0	0	0.0	1	0.0	0	0.0	
Normal	6144 (87.4)	157	97.5	2298	92.5	1386	87.4	1882	82.4	421	82.5	
Abnormal	878 (12.5)	4	2.5	186	7.5	199	12.6	400	17.5	89	17.5	
1st risk	545 (7.8)	4	2.5	130	5.2	126	7.9	239	10.5	46	9.0	
2nd risk	211 (3.0)	0	0.0	39	1.6	43	2.7	101	4.4	28	5.5	
3rd risk	122 (1.7)	0	0.0	17	0.7	30	1.9	60	2.6	15	2.9	
No. of Diagnosis number of abnormal Electrocardiogram (ECG)												0.04
Normal	5031 (71.7)	109	67.7	1778	71.5	1135	71.6	1651	72.3	358	70.2	

Potential Risk Factor	Total	Number of years worked as a firefighter										P-value
		Less than 1 year		1~9 years		10~19 years		20~29 years		Over 30 years		
	N (%)	N	%	N	%	N	%	N	%	N	%	
1	1594 (22.7)	42	26.1	578	23.3	373	23.5	480	21.0	121	23.7	
2	333 (4.7)	7	4.3	114	4.6	68	4.3	121	5.3	23	4.5	
3	48 (0.7)	3	1.9	9	0.4	8	0.5	22	1.0	6	1.2	
4	7 (0.1)	0	0.0	1	0.0	0	0.0	5	0.2	1	0.2	
5	1 (0.01)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	
Type of diagnosis	7016											<.0001
Normal	5033 (71.7)	109	67.7	1779	71.6	1136	71.7	1651	72.3	358	70.2	
Ischemic heart disease	39 (0.6)	1	0.6	9	0.4	7	0.4	17	0.7	5	1.0	
PR interval disorder	33 (0.5)	2	1.2	3	0.1	9	0.6	18	0.8	1	0.2	
OT interval disorder	27 (0.4)	0	0.0	5	0.2	5	0.3	12	0.5	5	1.0	
Abnormal Q wave	35 (0.5)	0	0.0	10	0.4	8	0.5	16	0.7	1	0.2	
Abnormal R wave	19 (0.3)	1	0.6	7	0.3	7	0.4	4	0.2	0	0.0	
Abnormal T wave	107 (1.5)	4	2.5	17	0.7	30	1.9	45	2.0	11	2.2	
ST segment change	79 (1.1)	1	0.6	21	0.8	13	0.8	38	1.7	6	1.2	
WPW	10 (0.1)	0	0.0	1	0.0	5	0.3	2	0.1	2	0.4	
Sinus Arrhythmia	1057 (15.1)	33	20.5	430	17.3	240	15.1	282	12.4	72	14.1	
Atrial Arrythmia	33 (0.5)	0	0.0	12	0.5	6	0.4	12	0.5	3	0.6	
Ventricle Arrythmia	59 (0.8)	2	1.2	21	0.8	14	0.9	18	0.8	4	0.8	

Potential Risk Factor	Total	Number of years worked as a firefighter										P-value
		Less than 1 year		1~9 years		10~19 years		20~29 years		Over 30 years		
	N (%)	N	%	N	%	N	%	N	%	N	%	
Atrium Hypertrophy	3	0	0.0	0	0.0	2	0.1	1	0.0	0	0.0	
Ventricle Hypertrophy	106 (1.5)	2	1.2	31	1.2	19	1.2	43	1.9	11	2.2	
Right Axis deviation	37 (0.5)	2	1.2	20	0.8	10	0.6	4	0.2	1	0.2	
Conduction disorder	339 (4.8)	4	2.5	115	4.6	73	4.6	118	5.2	29	5.7	

* SD : standard deviation, IQR : interquartile range, WPW : Wolff-Parkinson-White syndrome

4.5 Discussions

This is the first study to compare and analyze the prevalence of chronic diseases and work-related diseases with the general population using data from the results of occupational health examinations conducted for all firefighters working in metropolitan in Korea. Until now, studies have been conducted on firefighters and general population groups working at some fire departments in each city and province in Korea, but the results have not been representative. Our research results have great strength in that they are representative. On the other hand, research on firefighters abroad is very active and diverse. Some states in the United States have suggested the risk of disease and cancer due to long-term exposure to firefighters in the working environment, and cohort studies using health outcomes are continuously being conducted. However, we have not been able to conduct analysis through the DB construction of special health examination result data at the national level, in Korea. In addition, the DB for each firefighter's individual job experience exposure matrix (JEM) is not systematically established. Therefore, in the event of a disease such as cancer, firefighters are in a difficult situation where they must prove the occurrence of work-related diseases.

In this respect, this study will be the first step to conduct a cohort study through tracking by utilizing the data of firefighter special health examination results in a barren firefighter research environment in Korea.

Occupational health examination for firefighters began in 2003 when the Ministry of Government Administration and Home Affairs asked the Ministry of Labor whether to apply a occupational health examination for firefighters. In July 2003, the Ministry of Government Administration and Home Affairs asked the Ministry of Labor whether to apply occupational health examinations under the Firefighters' Occupational Safety and Health Act, and received a reply that it was possible. After that, the National Fire and Emergency Management Agency requested each metropolitan government to conduct a occupational health examination for health management of the firefighters affiliated with it. Accordingly, local governments have been conducting health examinations every year in accordance with the circumstances of each province's budget, etc. In 2013, with the enactment of the Framework Act on Health, Safety and Welfare for Firefighters, occupational health examinations with some additional items taking into account the job characteristics of firefighters began to be conducted. In addition, the time when the diagnosis result data started to be notified from medical institutions to firefighting organizations was also from 2013.

Occupational health examination items for firefighters are divided into mandatory and optional items. Common test items include a questionnaire survey on symptoms using a work environment survey questionnaire, such as exposure evaluation of target hazardous factors, and an examination of an industrial medicine doctor about the target organ. At this stage, the health examination result data for the questionnaire conducted by the medical institution was not submitted to the fire department, so the related data cannot be analyzed. The fire department designates the form to receive data from medical institutions, because all questionnaire items are missing. The mandatory test items for special health examination consist of a total of 27 items.

The mandatory items included in the firefighter's occupational health examination results are divided into common examination items and examination items for each target organ. Common items include symptom survey using work environment survey questionnaire, such as exposure assessment of harmful factors, and questionnaire items through occupational medical examination on target organs. First, the items for examination through questionnaire are not included in the special health examination result DB construction items. The reason is that data from medical institutions are coded and not delivered to fire departments. This is a part to be resolved through cooperation between the fire department and the medical examination agency. Second, the target organ item includes basic physical examination and vital signs data. In addition, visual acuity test, hearing pure tone hearing test, respiratory system chest radiography, spirometer test, cardiovascular system include electrocardiogram, total cholesterol, HDL cholesterol, LDL cholesterol, and triglycerides, and blood glucose level. Liver function includes total protein, albumin, total bilirubin, hepatitis test items, kidney function includes creatine and urea nitrogen, and general blood test includes red blood cells, white blood cells, platelets, and white blood cell distribution.

The tracking management of the health level using the results of occupational health examinations for Korean firefighters has not been properly implemented at the level of firefighting organizations. It is the same at the national level as well as at the fire department headquarters of provinces. At the national level, the results of occupational health examinations for firefighters, which were carried out at the fire departments of 18 provinces, are reported and collected every year. The reality is that provincial fire department headquarters also collect the data from the examination results notified by the medical examination agency and report to the fire department. However, in the case of Seoul, since 2016, an analysis guideline has been established for systematic management of data on occupational health examination results for firefighters, and examination results are analyzed annually. However, at the level of the fire department, it is not possible to provide feedback for individual firefighters or fire department units. Systematic health care and management is still seen as the responsibility of individual firefighters. In particular, firefighters' health management plans have not been specifically established based on the analysis data for occupational health examinations. Therefore, the data of occupational health examination results must be tracked and managed in terms of health care for firefighters and prevention of occupational diseases, and is a very important part in the national aspect.

The firefighter's occupational health examination results need to be analyzed in connection with the firefighter's occupational environment exposure data. Here, the firefighter's occupational environment includes all of the disaster dispatch scene, dispatch route, and waiting space. In addition, it is necessary to establish a job exposure matrix including fire, rescue, first aid, administration, emergency dispatching, and administrative work period after starting work by selecting a job called firefighter, and analyzing it in connection with the results of health examination. This job exposure matrix data is important to understand the epidemiology of disease occurring among firefighters working in the Korean environment by analyzing data in connection with health care data of the Health Insurance Corporation, such as cancer diagnosis. For example, a group that engaged in firefighting activities at a fire site without SCBA in the 1970s is expected to show a large difference in health level, such as lung function, from the group that worked after the introduction of SCBA. In addition, since there will be a difference in exposure to diesel emissions between the group that worked at the fire station with smoke reduction systems installed in the fire station garage and the group that did not, it is expected to show a difference in health level. These data could provide an important basis for proving the health outcome of firefighters' exposure to work environment in the long term. To do this, data on exposure information on all current dispatch environments should be included in the DB establishment. Therefore, it is expected that the DB construction of occupational health examination results and the operation of a systematic analysis system can show various levels of firefighters' health in the firefighting environment in Korea.

4.6 Conclusions

The age- and sex- adjusted standardized prevalence rate at the disease stage calculated by the direct standardization method through comparison with the general population using the result of special health examination results for firefighters in metropolitan was 12.43% (male 16.91%, Female 7.76), in pulmonary ventilation disorders, the restricted was 16.87% (female 18.32%) and the combined was 2.07% (female 2.59%) higher than that of the general population. The general population was hypertension 17.93% (male 23.44%, female 12.19%), diabetes mellitus 5.30% (male 6.75%, female 3.80%), obesity 34.29% (male 46.94%, female 21.14%), and in the case of pulmonary ventilation disorder, obstructive 4.39% (male 6.13%, female 2.61%), in the case of noise-induced hearing loss by three tone average method, the right side was 4.41% (male 5.51%, female 3.29%), and the left side was 4.87% (male 6.41%, female 3.29%). In the four tone method, the right side was 6.99% (male 8.66%, female 5.28%), and the left side 7.92% (male 10.06%, female 5.71%) higher than that of firefighters. The gender-age adjusted standardized prevalence for each disease was hypertension 37.26% (male 52.45%, female

21.47%), diabetes mellitus 23.17% (male 30.79%, female 15.25%), metabolic syndrome was 87.21% (male 83.09%, female 91.49%)), obesity was 23.25% (male 33.08%, female 13.03%), which was higher in all firefighters than the general population. In addition, in the standardized prevalence ratio by indirect standardization, in the case of the disease stage, the firefighters were obesity 1.12 times (1.08-1.16) and the metabolic syndrome 1.33 times (1.26-1.40) higher than the general population. It was higher than that of the general population (1.29-1.40), hypertension 1.89 times (1.83-1.96), diabetes mellitus 1.36 times (1.31-1.41), and metabolic syndrome 1.85 times (1.81-1.90).

Chapter Ⅴ. Public Health Implications and Further Studies

5.1 Measurement of various occupational environments of firefighters

Unlike the general worker's occupational environment, which is one designated space, the firefighter's occupational environment is classified into three categories: a disaster scene, an emergency route, and a fire station waiting area. Our study presented results by measuring two of the three occupational environments. It was the working environment for the disaster scene and the waiting space of the fire station, and it was the result of the experimental study of Chapter 2 and Chapter 3. In Chapter 2, the primary and secondary exposures are measured, whereas in Chapter 3, the third exposure is measured in a continuous concept of exposure to hazardous substances. The experimental study in Chapter 2 confirmed that exposure at the fire scene can have acute health effects for firefighters as well as chronically. In addition, it was confirmed that cross-contamination at the fire scene could affect the indoor air quality of the fire station after returning home to the fire station. However, it was confirmed that the indoor air quality of the fire brigade was not only affected by the fire scene exposure, but also by diesel emissions from fire fighting vehicles and chemicals that were not systematically managed in the garage. In addition, cross-contamination of fire fighting protection suit, one of the personal protective equipments, was an opportunity to confirm the possibility that water quality could be contaminated in the long term. Therefore, it was found that measures such as gross decontamination must be necessary after exposure of dangerous substances at the fire scene. This could reduce the concentration of heavy metals in the wastewater in the fire suit laundry after returning home to the fire department. However, whether on-scene gross decontamination is a complete solution is not known exactly from the results of this study, so further research is needed.

In addition, the study in Chapter 2 is of great significance as the first study to measure the types and amounts of toxic substances that occur in a residential fire environment and simultaneously cause cross-contamination. In the future, it is necessary to establish a working environment exposure DB by taking into account the types and transfer cross-contamination of harmful substances occurring in various types of fire scenes such as factories, hospitals and construction scenes as well as residential fires. This study is of great significance as a result of the first step in this regard. These DB construction data will be able to provide a very important scientific evidence for determining the causality of exposure-results by analyzing them in connection with health data.

5.2 Firefighters' health status assessment

Firefighters' health level can be assessed in two ways. These are the incidence of injury by firefighting activities. and disease prevalence. In the study in Chapter 4, we confirmed the disease prevalence rate, which is the general health level of firefighters and the work-related health level. Due to the limitations of the cross-sectional study due to the nature of the data source, the effect of healthy workers could not be clearly confirmed, but the prevalence of the disease stage was lower than that of the general population, and the prevalence of the pre-disease stage was all higher than that of the general population. In other words, firefighters have a low distribution of disease groups due to the effect of healthy workers, but the ratio of risk groups is high. This has a common characteristic of the firefighter profession worldwide.

This study showed a representative health level by analyzing the data transmitted by metropolitan firefighters in Korea. However, it was not possible to show the level of health related to exposure data on the occupational environment. That is, as suggested in Chapter 4, metabolic syndrome, limited pulmonary ventilation disorder, and complex pulmonary ventilation disorder showed a higher distribution than the general population, but the causes such as association or causality could not be identified. This is also a task to be carried out in the future. In addition, a cohort study should be conducted through long-term follow-up observation of firefighters' occupational health examination results data at the national level. This will be a representative health study reflecting the occupational environment exposure of Korean firefighters, and the results reflecting various epidemiologic characteristics can be confirmed.

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국문초록

한국 대도시 소방관들의 유해물질 직접· 간접 노출과 질병유병률

서울대학교 대학원

보건학과 역학전공

김 수 진

서론

세계보건기구 산하 국제암연구소에서는 소방관의 직업적 노출을 인체발암가능인자인 그룹2B로 생체리듬 교란인자인 교대근무를 발암추정인자인 그룹2A로 규정하고 있다. 이외에도 소방관은 재난 등 소방활동현장에서 노출되는 위험물질에 의해서도 발암물질에 추가적으로 노출될 수 있다. 소방관의 직업환경은 출동현장, 출동경로, 사무공간으로 분류된다. 특히, 출동현장 중 하나인 화재현장에서 발생하는 일산화탄소, 시안화수소, 포

름알데히드 등 10여종의 각종 독성물질은 인체 건강영향을 주는 강력한 위험인자 중 하나인 것으로 잘 알려져 있다. 소방관들은 재난현장에서 발생하는 위험요인에 지속적으로 노출됨으로써 질병부담을 증가시킨다. 따라서, 소방관의 근무환경과 재난현장 직업환경에 대한 위험요인에 대한 정보가 있다면, 예측가능한 건강영향을 예방할 수 있을 것이다. 본 연구의 목적은 대도시에 근무하는 소방관들의 출동현장과 사무공간에 대한 직업환경을 측정하고 방화복 사용, 세척, 관리에 대한 보건학적 인식을 평가한다. 더불어 대도시 소방관 전수코호트를 대상으로 특수건강진단결과를 이용하여 일반인구집단과 만성병과 직업관련성 질환의 표준화 유병률(비)를 비교 평가함으로써 건강수준을 평가한다.

방법

첫 번째 연구는, 서울시에 근무하는 화재진압과 인명구조 업무를 수행하는 소방관 1,097명을 대상으로 21일간 설문조사를 실시하여 40.3%의 응답률을 보였다. 이 조사에서 소방관들이 사용하는 개인보호장비 중 하나인 방화복의 사용, 세탁, 관리정도와 보건학적 인식간에 연관성을 평가하였다. 또한, 소방관들의 직업환경 중 하나인 재난현장 활동단계를 평가하였다. 국내에서 가장 많은 발생을 보이는 주택화재 발생을 직업환경으로

화재현장에서 1차적으로 발생하는 오염과 2차적으로 발생하는 방화복 교차오염에 대하여 오염물질의 종류와 양에 대하여 실험을 하였다. 교차오염 평가는 방화복을 직업환경의 위험정도에 따라 4개 그룹으로 나누어 측정하였다. 이때 1차오염과 2차오염에서의 공기포집을 통해 12개 항목을 분석하였다. 또한, 방화복에 묻은 오염물질은 세탁물을 추출하여 24개 항목에 대하여 수질분석을 수행하였다. 설문조사와 실험연구를 통해 도출된 문제점에 대한 대책마련을 위하여 델파이 전문가 조사 방법으로 실행가능성과 효과성을 높일 수 있는 구체적인 정책을 제안하였다. 델파이 전문가 조사의 참여대상자는 소방현장과 방화복에 대한 선험적 실무경험과 연구경험이 많은 대학교수와 소방관을 7명을 대상으로 3라운드에 걸쳐 수행하였다. 두 번째 연구는, 소방관들의 직업환경 중 하나인 근무 중 대기공간인 소방청사 내에서의 근무환경을 평가하였다. 소방관들이 화재현장에서 철수하여 소방서로 복귀한 후 소방청사 내부와 소방차량에서 2차적으로 노출되는 화학적 유해물질의 실내공기질을 평가하였다. 서울시 소재 4개소방서를 무작위로 선정하였다. 2개소는 실험군으로 화재현장 소방활동이 종료되고 소방서로 귀소한 후에 측정하였다. 다른 2개소는 대조군으로 출동과 상관없이 평소 수준에서 실내공기질을 측정하였다. 소방안전지도 전산시스템을 이용하여 서울시에서 발생하는 모든 화재사고를 24시

간 모니터링하였고, 중급규모 이상의 사고에서 실험군이 출동하게 되는 경우 귀소 후 바로 실내공기질을 측정하였다. 11개 유해물질항목(미세먼지, 포름알데히드, 휘발성유기화합물, PAH, VCM, 산류, 석면, CO, CO2, NO2, O3)은 공정시험법에 따라 측정하였다. 세 번째 연구는 위험직군 중 하나로 분류되어 있는 소방관은 예측 불가능한 유해물질에 지속적, 반복적으로 노출되고 있으나 건강관리는 개인적 의무로 간주되고 있다. 따라서 본 연구에서는 매년 실시하는 소방관 특수건강진단 결과자료를 이용하여 대도시 소방관들의 만성질환인 고혈압, 당뇨, 대사증후군, 비만과 직업성 질환인 폐 환기장애(제한성, 폐쇄성, 복합성)와 소음성난청(4분법, 6분법)에 대하여 일반인구집단의 국건영 검진결과를 이용, 비교하여 직접표준화 방법으로 소방관과 일반인구집단 1,000명당 성-연령 표준화유병률과 간접표준화 방법으로 성-연령 표준화 유병비를 각각 산출하였다. 또한, 소방관 특수건강진단결과에 대한 역학적 특성을 분석하였다.

결과

첫 번째 연구에서, 소방관들은 재난현장에서 발암물질 발생가능성 인지도는 94.4%로 높았다. 이러한 보건학적 사고가 소방관 스스로의 안전을 지켜주는 방화복의 사용, 세탁, 관리에 대한 행동에는 영향을 주지 않는 것

으로 확인되었다. 다만, 방화복의 사용에서, 화재현장에서 소방활동 종료 후 방화복을 실제 벗어야 하는 위치에 대한 생각과 보건학적 사고간에는 연관성이 있었다 (AOR=1.92, CI 1.01-3.68). 화재현장과 방화복 오염도 평가결과, 화재현장에서는 급성 피부독성을 유발하는 시안화수소가 불완전연소(훈소화재)와 완전연소(화염화재) 모두에서 검출되었다. 시안화수소는 방화복 포집공기에서도 검출되어 화재현장에서의 방화복 착용이 매우 중요함을 확인하였다. 포름알데히드는 완전연소(화염화재)에서 노출기준 TWA 0.3을 초과하여 방화복에서 검출되었다. 이 외에도 시안화수소, 니켈은 신규 배정받은 방화복에서도 검출되었으나 위험수준을 초과하지는 않았다. 시안화수소는 방화복 모든 실험그룹에서 검출되었고, 납, 산화철, 알루미늄, 카드뮴과 같은 중금속 물질도 공기포집에서 검출되었다. 방화복 교차오염 수질분석 결과에서는 구리, 니켈, 아연 등의 중금속이 발견되었다. 아크릴로니트릴은 화재에 한 번 노출된 경우보다 연속으로 노출된 경우 그 양이 2.1배 더 높은 양-반응관계를 보였다. 1급 발암물질인 나프탈렌은 훈소화재와 화염화재 모두 검출되었으나 훈소화재에서 더 높게 검출되었다. 구리와 그 화합물, 안티몬, 아크릴로니트릴, 디에틸헥실프탈레이트 4개 항목이 물환경보존법 기준 특정수질유해물질 폐수배출시설 적용기준을 초과하여 검출되었다. 이로써 화재현장에서의 방화복 오염이

심각함을 확인하였고 수질오염 가능성을 시사하였다. 또한, 상기 4개 항목이 폐수기준치를 초과하여 검출됨으로써 중재가능성 또는 정책적 조치가 필요함을 확인하였다. 설문조사와 실험연구에서 도출된 문제의 대안마련을 위하여 델파이조사를 수행한 결과, 설문조사와 화재현장과 방화복 오염도 실험결과를 중요도 부문에서는 소관분야 예산확보와 재난현장 오염물질 건강영향 위험성에 대한 교육실시가 가장 시급한 과제로 평가되었다. 실행가능성 부문에서는 재난현장 오염물질의 건강영향 위험성 교육실시, 개인보호장비 1차제염 교육실시, 방화복 등 개인보호장비 관리체계 개선과 체계적 운영을 위한 교육과정 개발이 가장 시급한 과제로 평가되었다. 두 번째 연구에서, 소방청사에서 측정한 유해물질 11종 중 3종이 국내·외 기준을 초과하였고, 1종은 국외기준에 육박하는 것으로 확인되었다. 특히 총휘발성유기화합물, 이산화탄소, 황산은 각 2.5배, 2.2배, 1.1배가 환경부와 고용노동부 기준보다 높았다. 또한, 포름알데히드와 황산의 경우, 실험군보다 대조군에서 더 높게 측정되었다. 세 번째 연구에서, 대도시 소방관 특수건강진단결과 전수자료를 이용하여 일반인구집단과 비교를 통해 직접표준화 방법으로 산출한 질병단계의 성-연령보정 표준화 유병률은 소방관에서 대사증후군 12.43% (남 16.91%, 여 7.76), 폐환기장애에서, 제한성은 16.87% (여 18.32%), 복합성은 2.07% (여 2.59%) 일반인구

보다 높았다. 일반인구는 고혈압 17.93% (남 23.44%, 여 12.19%), 당뇨 5.30% (남 6.75%, 여 3.80%), 비만 34.29% (남 46.94%, 여 21.14%), 폐환기 장애의 경우, 폐쇄성에서 4.39% (남 6.13%, 여 2.61%), 소음성 난청의 경우, 3분법에서 우측은 4.41% (남 5.51%, 여 3.29%), 좌측은 4.87% (남 6.41%, 여 3.29%) 이었고, 4분법에서 우측은 6.99% (남 8.66%, 여 5.28%), 좌측은 7.92% (남 10.06%, 여 5.71%) 소방관보다 높았다. 각 질환의 질병전단계 성-연령보정 표준화 유병률은 고혈압 37.26% (남 52.45%, 여 21.47%), 당뇨 23.17% (남 30.79%, 여 15.25%), 대사증후군 87.21% (남 83.09%, 여 91.49%), 비만 23.25% (남 33.08%, 여 13.03%)로 일반인구보다 소방관에서 모두 높았다. 또한, 간접표준화에 의한 표준화 유병비에서는, 질병단계의 경우, 일반인구보다 소방관에서 비만 1.12배 (1.08-1.16), 대사증후군 1.33배 (1.26-1.40) 높았고, 질병전단계의 경우, 소방관에서 비만 1.34배 (1.29-1.40), 고혈압 1.89배 (1.83-1.96), 당뇨 1.36배 (1.31-1.41), 대사증후군 1.85배 (1.81-1.90) 일반인구보다 높았다.

결론

방화복 설문조사를 통해 소방관의 보건학적 생각과 방화복의 사용, 세탁, 관리행동간에는 연관성이 없었으나, 보건학적 생각과 방화복의 올바른 사

용에 대한 생각 사이에는 연관성통계적 유의성을 보여 생각에서 행동으로 옮길 수 있는 통로를 마련해주는 것이 필요하여 이에대한 대책마련이 필요하다. 주택화재에서 발생할 수 있는 화재현장과 방화복 오염물질 발생 실험을 통해 재난현장에서의 소방관 직업환경을 평가하였다. 우리는 본 연구결과를 통해 주택화재에서 발생할 수 있는 유해물질의 종류와 양을 추정할 수 있었다. 물론 제한된 공간에서 발생한 유해물질의 종류와 양으로 과소추정 가능성이 있으나, 이 연구결과를 토대로 일반적으로 주택화재 현장에서 발생하는 유해물질의 종류와 양에 대한 DB를 구축할 수 있을 것이며, 화재현장에서 개인보호장비의 정확하고 철저한 착용이 중요함을 재확인하였다. 더불어, 방화복 오염에 의한 수질오염의 가능성 확인을 통해 후속연구와 정책실행이 필요함을 확인하였다. 또한, 소방관의 근무년수와 출동횟수에 대한 정보가 있다면 토대로 주택화재현장에서 노출되었던 유해물질의 누적노출양을 산정할 수 있을 것이다. 이러한 자료들은 소방관에게 질병이 발생하였을 때 업무관련성 질환여부를 입증할 수 있는 근거자료로 활용할 수 있을 것이다. 또한, 화재현장에서 교차오염이 발생한 방화복에 대하여 현장 긴급제염에 대한 소방정책을 실행하기 위한 강력한 과학적 근거를 제공할 수 있을 것이다. 본 연구결과는 소방관 방화복 안전한 사용과 보건정책을 추진할 때 적극 활용할 수 있을

것이다. 소방청사 실내공기질 평가를 통해 소방관 대기근무환경에 대한 직업환경 측정을 수행하였고, 실내공간과 차고에서 기준을 초과하는 항목들이 검출되었다. 또한, 재난현장 출동 후 귀소와 상관없이 소방차량 배기가스와 평소 화학적 유해물질의 누적이 청사 내 실내공기질 뿐만 아니라 장·단기적으로 소방관의 건강영향에 문제를 줄 수 있는 가능성이 있어 소방청사의 체계적 실내공기질 관리가 필요함을 확인하였다. 본 연구결과는 향후 서울시 소방청사 내 실내공기질 관리시스템이 정착과 개선에 활용될 수 있을 것이다. 마지막으로, 특수건강진단결과 분석을 통한 소방관과 일반인구집단과의 표준화 유병률 비교를 통해 질병단계의 경우, 건강근로자 효과가 있음을 추정할 수 있었다. 그러나 질병전단계의 경우 소방관에서 모든 만성질환에서 일반인구보다 높은 유병률을 보임에 따라 체계적인 건강관리 프로그램이 필요함을 확인하였다. 특히, 건강근로자 효과를 보이는 직군에서는 검진결과의 코호트 구축을 통한 연구를 통해 체계적인 추적, 관리시스템 구축이 필요하다. 끝.

주요어 : 소방관, 근무환경(출동현장, 사무/대기공간), 직접·간접노출, 보건학적 인식, 만성질환과 직업성질환, 표준화 유병률(비), 역학

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