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Associations between Recognition and Behaviors Regarding the Use, Washing and Management of Firefighting Protection Suits and Public Health Awareness of Occupational Exposure Risks among Firefighters

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Abstract: The firefighting protective suits (FPSs) of firefighters at fire scenes affect their health and safety. However, the association between firefighters' health awareness of occupational exposure risks and the FPS use, washing and management remains unclear. Therefore, this study aimed to evaluate the association between firefighters' health awareness of occupational exposure risks and their recognition, behaviors regarding the use, washing and management of FPSs. This study design is a cross-sectional study and used a web-based survey of the Seoul Metropolitan Government's electronic survey system. The survey was conducted on metropolitan firefighters performing shift work in charge of fire and rescue work for 21 days from 1 to 22 April 2019, with 1097 (40.3%) respondents. Characteristics of FPS use, washing and management and the association between thoughts and behaviors thereof and health awareness of occupational exposure risks were evaluated. Data of 1097 firefighters were analyzed using the SAS 9.4 statistical package, chi-square test and logistic regression analysis. Firefighters' fire scene awareness rate of possible carcinogens was 94.4%. There was an association between public health thinking of occupational exposure risks and the correct use of an FPS for one's own safety (AOR 1.97. 95% CI 1.02–3.80). However, no association was shown between correct FPS use (AOR 1.49, 95% CI 0.48–4.59), washing (AOR 2.50, 95% CI 0.93–6.68) and management (AOR 1.38, 95% CI 0.75–2.50) behaviors. This study analyzed the relationship between the use, washing and management of personal protective equipment called firefighting clothing and firefighters perceived occupational exposure risks. This study found an association between the health awareness of occupational exposure risks and recognition of the correct use of FPSs at fire scenes but not between using, washing and managing behaviors of FPSs. This study is the first to analyze the relationship between firefighting clothing and occupational health awareness level. The results confirm that future interventions are required to help firefighters practice desirable behaviors toward FPSs and provided evidenced data for preventing occupational diseases among firefighters. Therefore, this study can be used to develop a firefighter occupational health curriculum and establish health and safety plans from mid- to long-term perspectives for firefighters' safety against occupational exposure risks.

Keywords: firefighting protection suits (FPSs); public health awareness; occupational exposure risk; firefighter; recognition; behavior

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1. Introduction

Fires that occur in industrial societies generally generate many toxic substances, such as carbon monoxide, polycyclic aromatic hydrocarbons (PAH), volatile organic compounds

(VOC) and formaldehyde, as combustible materials are burned [1–7]. These substances adversely affect the human body and can cause diseases such as cancer [8–15]. Therefore, the correct use, washing and management of personal protective equipment (PPE) is very important for firefighters engaged in firefighting activities at fire scenes [16–18]. The PPE worn by firefighters during fire scenes includes firefighting protective suits (FPSs), self-contained breathing apparatus (SCBA) cylinders, face masks, helmets, firefighting boots and gloves. PPE prevents toxic substances generated during combustion from being inhaled through the respiratory system or absorbed through the skin [17,19]. Therefore, it is important for firefighters to wear PPE when performing firefighting activities at disaster sites, including all fires, and to take emergency decontamination actions to remove contaminants from the site after firefighting activities for disease prevention, hygiene and safety management [17,20–22]. The decontamination effect of FPSs worn at fire scenes has been proven in several studies [21,23,24]. Some studies have analyzed the relationship between firefighters' PPE cleaning and storage behavior and health beliefs [25,26]. Another study confirmed an association between firefighters' perceptions of occupational exposure risk and health beliefs, depending on the level of exposure to hazardous substances at disaster sites [27]. There was also a study that found that the behavior of washing contaminated SCBA was influenced by the presence or absence of prior training [28]. However, no research has yet been published on the relationship between individual firefighters' health awareness, occupational exposure risks and the use, washing and management of FPSs. In particular, no research has been published on the FPS worn by firefighters before entering a fire scene and their awareness of occupational exposure risks. A recent study found that fabrics used to make firefighting suits contain measurable amounts of chemicals called per- and polyfluorinated substances (PFAS), potentially carcinogenic chemicals [29]. Therefore, this study is very important in that it provides data so that firefighters can prevent occupational diseases through occupational health awareness that hazardous substances generated at the scene of dispatch and those contained in FPSs can affect their health. Firefighters are a population group that are mentally and physically much healthier than the general population, but they can be diagnosed with occupational cancer due to the hazardous substances they are exposed to when dispatched to various accident scenes [15,30–32]. Therefore, it is very important for new firefighters to be aware of the risk of occupational exposure in firefighting activities and to take preventive actions. For this reason, this study is necessary from an occupational health perspective. Firefighters are not properly aware of the hazards and dangers of FPSs 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 study aimed to evaluate the association of recognition, behavior of use, washing and management of FPSs and public health awareness with occupational exposure risks among firefighters.

2. Materials and Methods

2.1. Korean Firefighter's FPS Survey (KFFS)

This survey focused on FPS among PPE to determine its current status. This was conducted to find improvements at firefighting scenes in each field in order to solve problems in the use, washing and management aspects of FPS derived from the survey results. In the Fire Science Research Center, Seoul Metropolitan, Fire Service Academy, a questionnaire survey was conducted in five major domains among people in charge of fire suppression and rescue operations working in the Seoul metropolis. The specific contents of the questionnaire survey were as follows:

(1) Status of possession, use, washing and management of FPS
(2) Effectiveness of hygiene management system for contaminated FPS;
(3) Contribution of FPS to disease prevention;
(4) Fire dispatch status;
(5) Demographic and sociological information of questionnaire participants.

2.2. Study Setting

FPS is essential for PPE for firefighters to operate at disaster sites, such as fires. In Korea, the National Fire Agency regulate firefighters' PPE use. Firefighting suits used by firefighters in Korea are certified and inspected by the Korea Fire Institute (KFI). Compared to the US National Fire Protection Association (NFPA), Europe's European Norm (EN) and the International Organization of Standardization (ISO), the performance standard evaluation of Korea's KFI standard has of 15 items. The overall performance of domestic FPS was similar to that of overseas FPS. Fire protection equipment management regulations [33] specify that each of the 119 safety centers must have at least one washer and dryer specifically for FPS, but the actual supply status does not meet the legal standards. However, at the national level, safety management manuals for FPS use, washing, storage and PPE disuse, including FPS, are created and distributed so that firefighters who use them become familiar with them.

2.3. Study Design and Population

This study was a cross-sectional study. An online survey was conducted using the electronic survey system of the Seoul metropolitan government. The firefighters participating in this study were instructed to complete the survey anonymously online, and informed consent was obtained from all participants. As of April 2019, the survey participants included 2722 shift workers performing fire and rescue work among 7002 career firefighters in the Seoul metropolitan area. As a result, 1097 people responded to the survey, and data from 1097 people who agreed to participate in the study were analyzed (Figure 1).

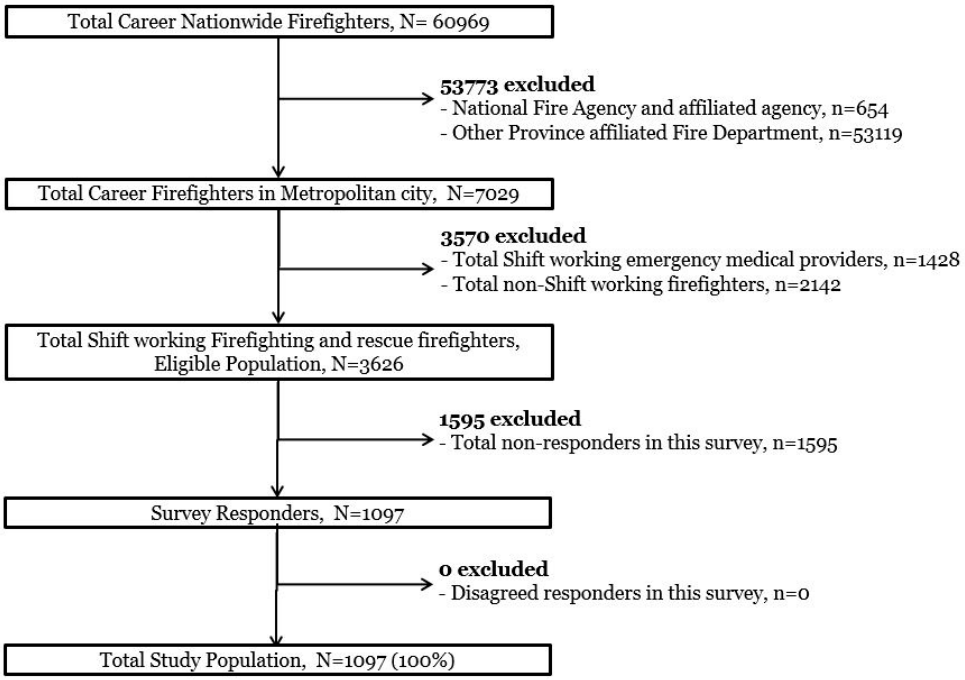

Figure 1. Study population in this study.

2.4. Data Collection

To investigate the overall use, washing and management of FPS used as PPE worn by firefighters at disaster sites, survey items were developed based on prior research and interviews with experts in the field. After revising the survey items using a pilot survey, the final survey questions were developed. The survey was conducted over 22 days, from 1 to 22 April 2019. Survey participants were encouraged to participate actively by explaining the purpose and importance of the survey to the Seoul Metropolitan Government Fire Department using official letters, e-mails and SMS. Of them, 1097 responded, resulting in a survey participation rate of 40.3%. Additionally, at least 30% of fire departments

participated in the survey. The main information collected in the survey was as follows: (1) socio-demographic information (gender, age, total period of time worked as a firefighter, current job duties, rank, period of performing fire work and rescue work in shift work) and individual fire dispatch statistics; (2) use of FPS (fire scene) and experience of not wearing both the top and bottom of the FPS, where the FPS was removed after firefighting activities were completed, where FPS were thought to be good to remove and the experience of riding a firefighting vehicle after storing the FPS separately after the end of firefighting activities at the fire scene); (3) washing of FPS (how to wash FPS, satisfaction with washing cleanliness when using a washing machine dedicated to FPS, monthly average number of FPS washes, degree of separate washing of the inner and outer layers of FPS, timing of washing FPS, type of washing detergent for FPS and awareness of FPS drying method presence or absence) and (4) management of FPS (how to store FPS, familiarity with the safety management manual for FPS and degree of awareness of how to use, store and wash FPS).

2.5. Public Health Awareness with Occupational Exposure Risk Measure

In this study, firefighters were asked the following questions to measure their level of health awareness of occupational exposure risks at a personal level: "Do you think that substances that can cause cancer in the human body may be generated at disaster sites such as fires?". If survey participants answered "yes", it was measured that they had health awareness with occupational exposure risks, and if they answered "no", it was measured that they had no health awareness. That is, firefighters performed cognitive assessments of their occupational exposure risk.

2.6. Variables

The main exposure variable is health awareness with occupational exposure risks recognized by firefighters. The primary end point is the recognition of a place where firefighters think it is good to take off their FPS after completing firefighting activities, which evaluates their thoughts on occupational risk awareness. The secondary end point is the actual place where the FPS was removed after firefighting activities had been completed at the fire scene, and the behavior was evaluated to determine whether it was an occupational hazard. The tertiary end point is the correct behavior regarding the cleaning method of FPS, and the fourth end point is the correct management behavior of FPS. Covariates included the following variables: gender, age, rank, job duties and experience of saving FPS in a separate space after working at a fire scene and boarding a fire truck. The reliability of the survey items was measured using Cronbach's alpha value, and use, washing and management of FPS were 0.72, 0.78 and 0.74, respectively.

2.7. Statistical Analysis

This study performed a distribution of categorical variables reported as percentages and a X^2-test analysis to confirm participants' characteristics and differences between the exposure variables. Thoughts and actions regarding the use, washing and management of FPS vary depending on the level of public health awareness of occupational exposure risks. To obtain the final model, interactions between the exposure variables and potential covariates were tested. Confounding factors were assessed, and precision level tests were performed. A multiple logistic regression analysis was performed to determine whether there was any association between FPS use, washing and management and public health-related factors and to determine recognition after adjusting for potential confounders, and we calculated the odds ratios (ORs), adjusted odds ratios (AORs) and their 95% confidence intervals (CI). In this study, AORs was calculated by adjusting for age, a confounding variable. 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. Analysis was conducted using SAS 9.4 (SAS Institute, Cary, NC, USA).

3. Results

The responses from 1097 firefighters were included in the analysis, and the results were as follows.

3.1. Demographic Characteristics of Eligible Study Population

A total of 1097 firefighters who participated in this study were divided into four groups based on their job duties, such as fire suppression, rescue and fire investigation (e.g., communication, safety officer, driver). Overall, 95.7% (1045) were male, 29.9% (320) were aged between 30 and 39 years, 76.0% (813) were married, 52.7% (564) were college graduates and 42.2% (451) had more than 20 years of experience as a firefighter. The most common answers were lieutenant (43.3% [463 people]) and firefighters (28.5% [305 people]) with more than 20 years of shift work experience. In terms of fire dispatch characteristics, the average monthly number of fire dispatches in the past year was 5 to 9 (28.0% [300 people]). The average monthly number of fire dispatches in the past year that required partial extinguishment or more and the average monthly number of fire dispatches that required washing of firefighting suits after extinguishing a fire were 28.0% (300 people). A total of 24.4% (261 people) had 1 to 2 cases, and 40.2% (430 people) had 1 to 2 cases (Table 1). The responses of 1097 firefighters were included in the analysis, and the results are in Table 1.

Table 1. Demographic characteristics of the duty-based job among firefighters.

Potential Risk Factor	Total N(%)	Firefighter		Rescuer		Fire Investigator		Other		*p*-Value
		N	%	N	%	N	%	N	%	
Gender										
Male	1071 (97.6)	624	96.6	181	100	21	87.5	245	99.6	<0.0001
Female	26 (2.4)	22	3.4	0	0	3	12.5	1	0.4	
Age										
20-29	78 (7.1)	42	6.5	18	9.9	1	4.2	17	6.9	<0.0001
30-39	332 (30.3)	155	24.0	102	56.4	9	37.5	66	26.8	
40-49	301 (27.4)	166	25.7	44	24.3	11	45.8	80	32.5	
≥ 50	386 (35.2)	283	43.8	17	9.4	3	12.5	83	33.7	
Marriage status										
Singled	237 (21.6)	121	18.7	63	34.8	5	20.8	48	19.5	0.001
Married	830 (75.7)	505	78.2	117	64.6	17	70.8	191	77.6	
Other	30 (2.7)	20	3.1	1	0.6	2	8.3	7	2.8	
Educational level										
High school	221 (20.1)	120	18.6	37	20.4	1	4.2	63	25.6	0.001
Junior college	272 (24.8)	149	23.1	65	35.9	4	16.7	54	22.0	
University	576 (52.5)	360	55.7	74	40.9	18	75.0	124	50.4	
Graduate school	28 (2.6)	17	2.6	5	2.8	1	4.2	5	2.0	
Number of years as a firefighter										
< 1	40 (3.6)	24	3.7	7	3.9	0	0	9	3.7	<0.0001
1–4	187 (17.0)	83	12.8	63	34.8	2	8.3	39	15.9	
5–9	181 (16.5)	87	13.5	48	26.5	4	16.7	42	17.1	
10–14	119 (10.8)	70	10.8	17	9.4	6	25.0	26	10.6	
15–19	108 (9.8)	70	10.8	8	4.4	6	25.0	24	9.8	
≥20	462 (42.1)	312	48.3	38	21.0	6	25.0	106	43.1	
Mean (SD)	15.6 (10.1)	17.4(10.3)		9.6(8.2)		14.0(6.4)		15.3(9.4)		
Job rank of firefighter										
Firefighter	183 (16.7)	86	13.3	58	32.0	1	4.2	38	15.4	<0.0001
Senior fire Fighter	216 (19.7)	100	15.5	59	32.6	5	20.8	52	21.1	
Fire Engineer	201 (18.3)	126	19.5	23	12.7	9	37.5	43	17.5	
Fire Lieutenant	474 (43.2)	314	48.6	39	21.5	8	33.3	113	45.9	
Over Fire Captain	23 (2.1)	20	3.1	2	1.1	1	4.2	0	0	

Table 1. *Cont.*

Potential Risk Factor	Total N(%)	Firefighter		Rescuer		Fire Investigator		Other		*p*-Value
		N	%	N	%	N	%	N	%	
Number of years with shift work as a firefighter										
<1	60 (5.5)	35	5.4	13	7.2	0	0	12	4.9	<0.0001
1–5	246 (22.4)	135	20.9	62	34.3	5	20.8	44	17.9	
5–9	197 (18.0)	100	15.5	45	24.9	9	37.5	46	18.7	
10–15	151 (13.8)	111	17.2	17	9.4	4	16.7	22	8.9	
15–20	122 (11.1)	77	11.9	11	6.1	3	12.5	34	13.8	
≥20	305 (27.8)	188	29.1	33	18.2	3	12.5	88	35.8	
Affiliation										
Field response team	519 (47.3)	219	33.9	145	80.1	23	95.8	132	53.7	<0.0001
119 Safety center	545 (49.7)	426	65.9	7	3.9	0	0	112	45.5	
119 Special rescue unit	33 (3.0)	1	0.2	29	16.0	1	4.2	2	0.8	
Monthly average number of fire dispatches in the past year										
<5	95 (8.6)	58	9.0	18	9.9	0	0	19	7.7	0.003
5–9	305 (27.8)	200	31.0	36	19.9	3	12.5	66	26.8	
10–14	294 (26.8)	183	28.3	43	23.8	9	37.5	59	24.0	
15–19	169 (15.4)	85	13.2	38	21.0	4	16.7	42	17.1	
20–24	83 (7.6)	51	7.9	12	6.6	1	4.2	19	7.7	
≥25	151 (13.8)	69	10.7	34	18.8	7	29.2	41	16.7	
Monthly average number of fire dispatches to incipient-stage or free-burning in the past year										
<1	50 (4.6)	21	3.3	13	7.2	0	0	16	6.5	0.001
1–2	265 (24.2)	181	28.0	30	16.6	3	12.5	51	20.7	
3–4	259 (23.6)	165	25.5	43	23.8	4	16.7	47	19.1	
5–7	214 (19.5)	111	17.2	42	23.2	5	20.8	56	22.8	
8–9	118 (10.8)	60	9.3	25	13.8	3	12.5	30	12.2	
10–14	76 (6.9)	50	7.7	8	4.4	4	16.7	14	5.7	
≥15	115 (10.5)	58	9.0	20	11.0	5	20.8	32	13.0	
Monthly average number of firefighting cases where you washed FPS * after returning fire station in the past year										
<1	164 (14.9)	79	12.2	20	11.0	2	8.3	63	25.6	<0.0001
1–2	442 (40.3)	284	44.0	64	35.4	12	50.0	82	33.3	
3–4	246 (22.4)	145	22.4	49	27.1	2	8.3	50	20.3	
5–7	124 (11.3)	66	10.2	25	13.8	1	4.2	32	13.0	
8–9	45 (4.1)	24	3.7	9	5.0	2	8.3	10	4.1	
10–14	40 (3.6)	25	3.9	8	4.4	1	4.2	6	2.4	
≥15	36 (3.3)	23	3.6	6	3.3	4	16.7	3	1.2	
Total	1097 (100)	646	100	181	100	24	100	246	100	

* FPS: firefighting protective suits.

3.2. General Characteristics of Using, Washing and Managing FPS among Firefighters

This is a general characteristic of FPSs worn by firefighters in fire scenes. Of the 1097 respondents, 999 (91.1%) had never had the experience of taking off their FPS tops and bottoms before returning to the fire scene. A total of 160 (35.4%), 154 (34.1%) and 69 (15.3%) answered that the reasons for removing the taking off their FPS before boarding a fire truck were to prevent contaminants from entering the fire scene into the fire truck, because it was stuffy and because it was smelly. The places where FPSs were actually taken off after the firefighting activities were the garage after returning home for 351 (41.6%) and the fire scene before boarding the vehicle for 77 (9.1%). However, when asked where they thought would be a good place to take off their FPS after working at a fire scene, 503 (47.0%), 353 (33.0%) and 208 (19.4%) answered the garage after returning home, the fire scene and the inside of the car while returning home, respectively. According to this response, there was a difference in priorities between the actual place of taking off the FPS and where they thought would be a good place to do so. In the past year, only 452 (41.2%) had removed their FPS tops and bottoms at least once before boarding a fire truck after completing activities at the fire scene. Additionally, when asked about their experience of removing their FPS, separating them, storing them and boarding a fire truck after completing firefighting activities at the

fire scene, only 165 (15.0%) responded. Regarding the method of bringing the FPS after firefighting at a fire scene, the order was taking it off inside the vehicle and fastening it to a chair, putting it on and boarding the fire truck by 694 (63.3%) and 477 (43.5%) firefighters, respectively. Few respondents indicated that they bring it in plastic bags or in collection boxes, with 13 (1.2%) and 5 (0.5%) respondents, respectively (Appendix A).

Among the main washing methods for FPSs, 827 (76.1%) used special washing machines, general washing machines and hand washing. A total of 504 participants (45.9%) were satisfied with cleanliness after washing. The average number of FPS washes per month was one to one. Two times was the most frequent, with 747 (68.1%) and 634 (57.8%) participants answering that they always washed the inner and outer layers of the FPS, respectively. When washing the FPS, 661 (60.3%) answered that the FPS was covered with foreign substances, such as soot, and 334 (30.4%) responded that it was when the FPS smelled like a burnt odor. When asked "Have you always washed the FPS worn at fire sites in the past year?" the majority of people (28.7% [315]) responded with "Normal," but 289 (26.4%) responded negatively. Among the types of detergents used when washing FPS, 590 (55.0%) and 481 (44.8%) responded that general neutral detergents and FPS-specific detergents were used. Finally, in terms of awareness of how to dry the FPS, 604 (55.1%) responded that they did not know (Appendix B).

Regarding how to store FPSs, 587 (54.1%) and 215 (19.8%) responded that they folded and stored it, hung it on a hanger, folded some and stored it together. When asked if they were familiar with the safety management manual for FPSs produced and distributed by the National Fire Agency, 623 (56.8%) responded that they were unfamiliar with it. Additionally, 235 participants (21.4%) responded that they did not know how well they knew how to use, store and wash FPSs. Only 56 (5.1%) knew the manual (Appendix C).

3.3. Association between FPS Characteristics of the Use, Washing, Management and Awareness of Public Health with Occupational Exposure Risk

The firefighters' use, washing and management of FPSs were classified according to their public health awareness and with occupational exposure risks. In the case of FPS use, depending on whether those involved in public health are aware of the occupational exposure risk, it is considered good to take off FPSs during the evacuation stage of the fire scene ($p = 0.05$), during the experience of storing FPS separately at the fire scene and when boarding a fire truck ($p = 0.03$). When washing the FPS, the extent to which the inner and outer layers of the FPS were washed separately ($p = 0.02$), the timing of washing the FPS ($p = 0.95$) and the type of laundry detergent used for the FPS ($p = 0.05$) depended on the public health awareness of occupational exposure risks. In the case of FPS management, there was a significant association ($p < 0.0001$) with the need to introduce an overseas advanced management system for FPSs depending on the presence or absence of health awareness of occupational exposure risks (Table 2, Figure 2).

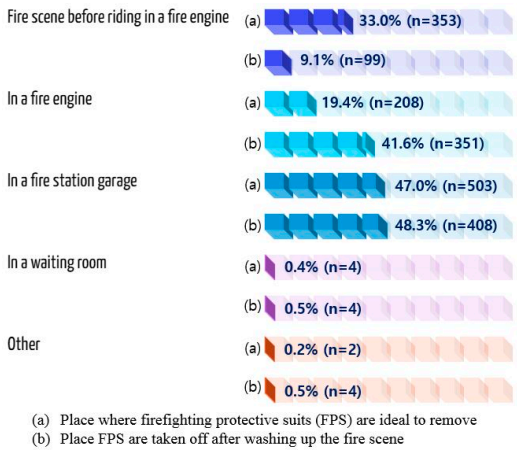

Figure 2. Recognition and implementation of FPS use.

Table 2. Association between the use, washing and management of the FPS and the awareness of public health with occupational exposure risk among firefighters.

Potential Risk Factor	Total N (%)	AG of Public Health with OER		Non- AG of Public Health with OER		χ^2	*p*-Value
		N	%	N	%		
FPS Using							
Place where FPSs are ideal to wear							
Fire scene before riding in a fire engine	353 (33.0)	341	32.9	12	19.4	3.72	0.05
In a fire engine	208 (19.4)	194	18.7	14	22.6		
In a fire station garage	503 (47.0)	471	45.5	32	51.6		
In a waiting room	4(0.4)	3	0.3	1	1.6		
Other	2 (0.2)	2	0.2	0	0		
Place FPSs are taken off after washing up the fire scene							
Fire scene before riding in a fire engine	99 (9.1)	73	7.1	4	6.5	0.57	0.96
In a fire engine	351 (41.6)	330	31.9	21	33.9		
In a fire stations garage	408 (48.3)	374	37.1	24	38.7		
In a waiting room	4 (0.5)	4	0.4	0	0		
Other	4 (0.5)	4	0.4	0	0		
Experience in riding fire engine after fire activities at fire scene, storing FPS							
Yes	165 (15.0)	150	14.5	15	24.2	4.31	0.03
No	932 (85.0)	885	85.5	47	75.8		
FPS Washing							
Wash by separating the inner and outer layer of the FPS							
Always	634 (57.8)	607	58.6	27	43.5	10.8	0.02
Sometimes	220 (20.0)	199	19.2	21	33.9		
Commonly	99 (9.0)	91	8.8	8	12.9		
Not really	96 (8.7)	91	8.8	5	8.1		
Not at all	48 (4.4)	47	4.5	1	1.6		
When to wash FPS							
After every fire activation	75 (6.8)	71	6.9	4	6.5	0.31	0.95
When foreign body such as soot gets on the FPS	661 (20.3)	623	60.2	38	61.3		
When your FPS smells burned	333 (30.4)	313	30.2	20	32.3		
Whether or not FPS is washed after working at a fire scene							
Always	198 (18.0)	190	18.4	8	12.9	3.01	0.56
Sometimes	295 (26.9)	279	27.0	16	25.8		
Commonly	315 (28.7)	296	28.6	19	30.6		
Not really	251 (22.9)	233	22.5	18	29.0		
Not at all	38 (3.5)	37	3.6	1	1.6		
Monthly average number of FPS washed (freq)							
1–2	747 (68.1)	710	68.6	37	59.7	4.6	0.03
3–4	244 (22.2)	229	22.1	15	24.2		
5–6	51 (4.6)	48	4.6	3	4.8		
≥7	55 (5.0)	48	4.6	7	11.3		
Satisfaction with cleanliness after FPS washing							
Very satisfied	49 (4.5)	41	4.0	8	12.9	17.5	0.001
Satisfied	299 (27.3)	278	26.9	21	33.9		
Normal	504 (45.9)	476	46.0	28	45.2		
Not satisfied	190 (17.3)	186	18.0	4	6.5		
Absolutely not satisfied	55 (5.0)	54	5.2	1	1.6		
Wash by separating the inner and outer layer of the FPS							
Always	634 (57.8)	607	58.6	27	43.5	10.8	0.02
Sometimes	220 (20.0)	199	19.2	21	33.9		
Commonly	99 (9.0)	91	8.8	8	12.9		
Not really	96 (8.7)	91	8.8	5	8.1		
Not at all	48 (4.4)	47	4.5	1	1.6		
Types of laundry detergents for FPS							
General neutral detergent	591 (53.9)	550	53.1	41	66.1	3.7	0.05
FPS exclusive detergent	482 (43.9)	462	44.6	20	32.3		
Others	24 (2.2)	23	2.2	1	1.6		

Table 2. *Cont.*

Potential Risk Factor	Total N (%)	AG of Public Health with OER		Non- AG of Public Health with OER		χ^2	*p*-Value
		N	%	N	%		
Awareness of how to dry FPS							
Yes	591 (53.9)	550	53.1	41	66.1	3.68	0.05
No	482 (43.9)	462	44.6	20	32.3		
FPS Management	24 (2.2)	23	2.2	1	1.6		
Need to introduce advanced FPS overseas management system							
Yes	859 (78.3)	830	80.2	29	46.8	38.4	<0.0001
No	238 (21.7)	205	19.8	33	53.2		
Minimum required number of FPS when introducing advanced overseas							
3 set	573 (66.7)	547	52.9	26	41.9	9.1	0.02
4 set	209 (24.3)	207	20.0	2	3.2		
5 set	61 (7.1)	60	5.8	1	1.6		
≥6 set	16 (1.9)	16	1.5	0	0		
Awareness how to use, store and wash FPS							
Strongly agree	56 (5.1)	53	5.1	3	4.8	3.53	0.47
Agree	235 (21.4)	224	21.6	11	17.7		
Neutral	571 (52.1)	542	52.4	29	46.8		
Disagree	215 (19.6)	198	19.1	17	27.4		
Strongly disagree	20 (1.8)	18	1.7	2	3.2		
Familiarize yourself with the safety management manual for FPS							
Yes	474 (43.2)	449	43.4	25	40.3	0.22	0.63
No	623 (56.8)	586	56.6	37	59.7		
Total	1097 (100)	1035	100	62	100		

FPS, firefighting protective suits; AG, awareness group; OER, occupational exposure risk; freq, frequency.

3.4. Proper Use, Washing, Management of FPS by Demographic Factors and Occupational Health Related Awaress

The effect of the degree of the recognition of occupational hazardous substances occurring at the fire scene on the use, washing and management of FPSs was confirmed. The use of the FPS was analyzed by dividing it into two areas: the place where FPSs were actually removed after firefighting activities at the fire scene and the place where FPSs were considered good to take off. 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) (Table 3). When a possibility of the occurrence of hazardous substances at a disaster scene was recognized, the actual taking off of fire protection at the fire scene was 1.24 times higher (95% CI 0.43–3.57) (Table 4). In the case of washing FPSs, recognizing the possibility of the occurrence of hazardous substances at the disaster scene and becoming familiar with the drying method when washing FPSs was 1.35 times higher (95% CI 0.81–2.31) (Table 5). In the case of recognizing the possibility of the occurrence of hazardous substances in the disaster site, the case of good familiarity with the safety management manual for fire protection was 1.26 times higher (95% CI 0.74–2.16) (Table 6, Figure 3).

Table 3. Multiple logistic regression analysis of public health awareness with occupational exposure risk factors and proper thinking of take-off places of FPSs.

Potential Risk Factors	Unadjusted Model			Adjusted Model		
	OR	95% CI		AOR	95% CI	
Outcomes: Proper recognition of take-off place of FPS	1.99	1.04	3.80	1.97	1.02	3.80
Age						
20–29	Ref			Ref		
30–39	1.17	0.70	1.96	1.02	0.56	1.87
40–49	0.96	0.56	1.62	0.79	0.36	1.71
Over 50	0.68	0.40	1.14	0.44	0.19	1.04
Job rank of firefighter						
Firefighter	Ref			Ref		
Senior Fire Fighter	1.16	0.77	1.75	1.20	0.74	1.95
Fire Engineer	0.71	0.46	1.09	0.96	0.51	1.81
Fire Lieutenant	0.78	0.54	1.12	1.69	0.83	3.44
Over Fire Captain	1.37	0.57	3.30	3.69	1.23	11.05
Job duty of firefighter						
Fire suppression	Ref			Ref		
Fire investigation	2.33	1.03	5.30	1.84	0.78	4.30
Rescuer	2.37	1.67	3.35	2.08	1.43	3.01
Incident safety officer, fire engine driver, communication	1.76	1.29	2.40	1.69	1.23	2.33
Experiences in riding fire engine after fire activities at fire scene, storing FPS						
No	Ref			Ref		
Yes	1.52	1.08	2.13	1.59	1.11	2.26

FPS, firefighting protective suits; OR, odds ratio; AOR, adjusted odds ratio; Ref, reference; CI, confidence interval. Adjusted Model; Hosmer and Lemeshow Goodness-of-Fit Test, chi-square; 2.56, *p*-value: 0.95, c-statistic; 0.64.

Table 4. Multiple logistic regression analysis of public health awareness with occupational exposure risk factors and proper take-off place of FPSs.

Potential Risk Factors	Unadjusted			Adjusted Model		
	OR	95% CI		AOR	95% CI	
Outcomes: Proper take-off place of FPS	1.14	0.40	3.25	1.49	0.48	4.59
Age						
20–29	Ref			Ref		
30–39	0.62	0.21	1.82	0.49	0.12	1.95
40–49	1.54	0.57	4.17	0.71	0.14	3.77
Over 50	1.35	0.51	3.61	0.92	0.16	5.43
Job rank of firefighter						
Firefighter	Ref			Ref		
Senior Fire Fighter	0.81	0.29	2.21	0.99	0.27	3.65
Fire Engineer	2.06	0.87	4.91	2.27	0.53	9.66
Fire Lieutenant	1.88	0.86	4.11	1.48	0.31	7.00
Over Fire Captain	0.95	0.11	8.06	1.41	0.12	16.54
Job duty of firefighter						
Fire suppression	Ref			Ref		
Fire investigation	2.28	0.50	10.41	1.72	0.34	8.62
Rescuer	1.50	0.68	3.31	2.20	0.95	5.08
Incident safety officer, fire engine driver, communication	5.08	2.98	8.64	5.19	2.98	9.02
Experiences in riding fire engine after fire activities at fire scene, storing FPS						
No	Ref			Ref		
Yes	3.10	1.85	5.18	2.59	1.48	4.53
Proper thinking of take-off place of FPS						
No	Ref			-		
Yes	19.95	10.31	38.60			

FPS, firefighting protective suits; OR, odds ratio; AOR, adjusted odds ratio; Ref, reference; CI, confidence interval. Adjusted Model; Hosmer and Lemeshow Goodness-of-Fit Test, chi-square; 6.04, *p*-value: 0.64, c-statistic; 0.76.

Table 5. Multiple logistic regression analysis of public health awareness with occupational exposure risk factors and proper washing behaviors of FPSs.

Potential Risk Factors	Unadjusted			Adjusted Model		
	OR	95% CI		AOR	95% CI	
Outcomes: Proper washing behaviors of FPS	1.48	0.69	3.16	2.47	0.92	6.62
Age						
20–29	Ref			Ref		
30–39	0.46	0.71	3.01	1.03	0.38	2.76
40–49	0.35	0.65	2.80	1.38	0.41	4.59
Over 50	1.48	0.72	3.02	1.55	0.41	5.89
Job rank of firefighter						
Firefighter	Ref			Ref		
Senior Fire Fighter	0.33	0.78	2.24	1.50	0.69	3.28
Fire Engineer	1.11	0.64	1.93	1.41	0.53	3,75
Fire Lieutenant	1.26	0.79	1.99	0.92	0.31	2,77
Over Fire Captain	0.54	0.12	2.43	0.47	0.07	3.03
Job duty of firefighter						
Fire suppression	Ref			Ref		
Fire investigation	0.18	0.02	1.33	0.20	0.02	1.61
Rescuer	1.14	0.76	1.71	1.07	0.62	1.83
Incident safety officer, fire engine driver, communication	0.41	0.26	0.66	0.51	0.30	0.86
Monthly average number of FPS washed						
1–2	Ref			Ref		
3–4	2.40	1.68	3.41	2.37	1.54	3.66
5–6	1.77	0.88	3.57	1.46	0.64	3.37
Over 7	3.71	2.03	6.78	3.95	1.92	8.13
Satisfaction with cleanliness after FPS washing						
No	Ref			Ref		
Yes	1.71	1.24	2.35	1.83	1.25	2.68
Wash by separating the inner and outer layers of the FPS						
No	Ref			Ref		
Yes	1.65	1.09	2.51	1.95	1.17	3.23
Types of laundry detergents for FPS						
General neutral detergent	Ref			Ref		
FPS exclusive detergent	1.40	1.03	1.91	1.13	0.78	1.65
Taking off firefighter FPS at fire scene						
No	Ref			Ref		
Yes	1.46	0.83	2.56	1.84	0.98	3.44

FPS, firefighting protective suits; OR, odds ratio; AOR, adjusted odds ratio; Ref, reference; CI, confidence interval. Adjusted Model; Hosmer and Lemeshow Goodness-of-Fit Test, chi-square; 9.50, *p*-value: 0.30, c-statistic; 0.70.

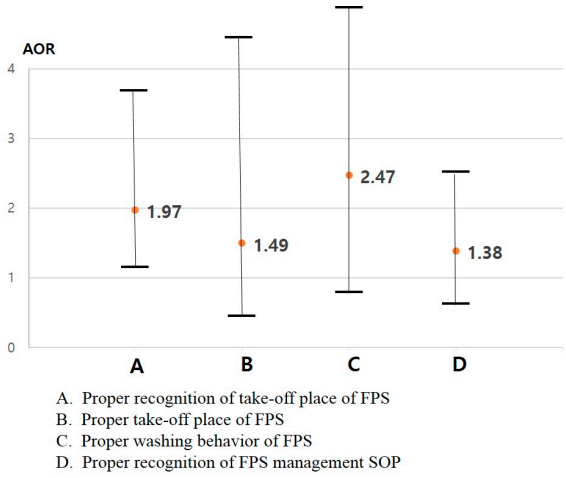

Figure 3. AOR (95% CI) of recognition and behaviors regarding the use, washing, management of FPSs by health awareness of occupational exposure risks.

Table 6. Multiple logistic regression analysis of public health awareness with occupational exposure risk factors and proper management SOPs of FPSs.

Potential Risk Factors	Unadjusted			Adjusted Model		
	OR	95% CI		AOR	95% CI	
Outcomes: Proper recognition of FPS management SOP	1.13	0.67	1.91	1.38	0.75	2.50
Age						
20–29	Ref			Ref		
30–39	1.44	0.81	2.55	0.76	0.39	1.49
40–49	0.95	0.53	1.67	1.24	0.52	2.95
Over 50	0.49	0.28	0.85	2.20	0.85	5.66
Job rank of firefighter						
Firefighter	Ref			Ref		
Senior Fire Fighter	1.18	0.73	1.19	0.89	0.50	1.56
Fire Engineer	0.97	0.61	1.57	0.77	0.37	1.60
Fire Lieutenant	0.47	0.32	0.72	0.96	0.43	2.15
Over Fire Captain	0.66	0.24	1.83	0.68	0.20	2.36
Job duty of firefighter						
Fire suppression	Ref			Ref		
Fire investigation	0.68	0.26	1.75	0.99	0.37	2.63
Rescuer	1.03	0.38	2,78	0.95	0.61	1.47
Incident safety officer	0.88	0.18	4.21	0.83	0.21	3.21
Fire engine driver	0.58	0.22	1.57	1.09	0.76	1.57
Emergency communicator	0.39	0.05	2.92	1.42	0.23	8.90
Education level of firefighter						
Less than High school	Ref			Ref		
College	1.12	0.75	1.67	1.31	0.84	2.02
University	1.54	1.09	2.19	0.96	0.65	1.42
Over Graduate school	0.87	0.36	2.12	1.52	0.60	3.85
Taking off FPS at fire scene	1.15	0.72	1.84	1.01	0.61	1.66

SOPs, Standard operation procedures; FPS, firefighting protective suits; OR, odds ratio; AOR, adjusted odds ratio; Ref, reference; CI, confidence interval. Adjusted Model; Hosmer and Lemeshow Goodness-of-Fit Test, chi-square; 2.36, *p*-value: 0.96, c-statistic; 0.64.

4. Discussion

In this study, we analyzed the association between the use, washing and management of FPSs, an essential PPE used by firefighters, and individuals' perceptions of occupational exposure risks. This study would like to continue discussions on firefighters' use, washing and management behavior; recognition of FPS and public health awareness regarding occupational exposure risks.

4.1. Occupational Health Exposure Risks and PPE for Firefighters

The International Agency for Research on Cancer (IARC) upgraded firefighters' occupational environment and cancer risk factors in Group 1 [11]. This was the highest level raised in 10 years since designated as a Group 2B carcinogen [34]. The reason the IARC has designated firefighters as Group 1 carcinogens is that not only does the shift work pattern cause circadian disruption but the firefighters' occupational exposure itself is also dangerous [35,36]. That is, occupational exposure in firefighters was evaluated as having the same risk in terms of occupational health as occupational exposure in painters [37]. Shift workers performing fire work all wear PPE to prevent exposure to various chemical and toxic substances generated at fire scenes. When firefighting activities are completed, emergency decontamination of PPE, including FPSs, is performed at the fire scenes. This washes away toxic substances from PPE that can cause cancer and is an effort to reduce the risk of occupational cancer. Therefore, it is important for individual firefighters to properly use, clean and maintain FPSs. In the long run, firefighters' FPS use, washing and management behavior may act as factors that indirectly affect the occurrence of occupational diseases.

4.2. Implications for the Impact of Firefighters' Personal Occupational Exposure Health Awareness on the Use, Washing and Management of FPS

Among the studies conducted thus far in Korea, no study has been conducted on the association between the use, washing and management of FPSs and public health awareness of occupational exposure risks. Three recently published studies in the United States and the United Kingdom are the only similar overseas studies. In our study, the awareness rate of FPS washing and drying methods and safety management manuals among in-service firefighters was low (44.9%). Specifically, in the fire scene evacuation stage, the number of cases of boarding a fire truck and returning to the fire station while wearing PPE, including an FPS, without first engaging in emergency decontamination was very high at 90.9%. This creates an inflow passage for on-scene contaminants into the fire engine and fire department building, causing cross-contamination. The overall awareness rate of toxic substances in fire scenes was high (90.9%). However, our study showed that the use, washing and management of PPE, including FPSs, are not generally performed systematically. Two studies conducted in the United States examined the differences between career and volunteer firefighters and compared and evaluated firefighters' behavior and practices regarding the use, washing, storage and disposal of firefighting clothing. In previous studies, compared to volunteer firefighters, the number of career firefighters participating in the study was significantly smaller, the participants were younger and the number of years of service as firefighters tended to be longer [25]. Researchers have investigated the provision rate for personal protective equipment used in the field by volunteer and career firefighters. The payment rates for each PPE for the career firefighter group were as follows: gloves (100%); turnout gear, helmet, hoods and footwear (95% each); SCBA, eye protection and masks (89% each) and hearing protection (37%). The PPE provision rate was higher in the volunteer firefighter group than in the career firefighter group. However, considering the limited number of career firefighters who participated in the study, the results may not be generalizable. The study conducted in the United Kingdom (UK) was a survey in which 24% of firefighters responded. The majority of firefighters (62%) were surveyed as having not received training on the health effects of exposure to pollutants, and of those who received training, 93% responded that the training was useful, and 98% thought the training was valuable [38].

In our study, of the respondents, 297 (27.1%) owned one set, 696 (63.5%) had two sets, 98 (8.9%) had three sets and 6 (0.6%) had four or more sets. The Fire Equipment Management Act stipulates two FPSs per person. Of the firefighters, 27.1% did not meet the legal retention standards. That is, 27.1% of firefighters have no choice but to wear dirty and contaminated FPSs when they are called out during a series of fires. This does not meet the firefighter health and safety recommendation standards of the US NFPA 1581. Additionally, in Korea, washing standards for FPSs are not strictly specified. When asked about the minimum number of fire protection suits required when conducting field activities, 563 (51.3%), 484 (44.1%), 39 (3.6%) and 11 (1.0%) people responded that they had two, three, four or five or more sets, respectively. In reality, additional allocations are required for firefighters who perform fire duties with fewer than two sets of FPSs. In addition, to operate a system for changing contaminated FPSs at fire scenes for the safety and health of individual firefighters, changes such as the revision of the legal reserve quantity will be necessary.

A previous study investigated the storage location of an FPS [26]. This is important for the proper management of FPSs. Because of the study, considering career firefighters, 74% kept it in a locker at the fire station, 21% in a personal vehicle and 11% in a fire truck. Of the volunteer firefighters, 53% kept it in their personal vehicles, 50% in their lockers at the fire station and 9% in their fire trucks and homes. There was a statistically significant difference in the storage location of FPSs between the two groups (p = 0.027). In our study, there were no results in which the FPS was stored; however, storage methods were investigated. Of the respondents, 587 (53.5%) folded and stored their FPSs, 283 (25.8%) hung them on hangers, folded some of them and stored them together and 215 (19.6%) hung them on

hangers and stored them ($p < 0.0001$). In a previous study, the frequency of washing FPSs among career firefighters was 53% after extinguishing a fire, 42% when complying with standard operation procedures (SOPs) and 37% when they saw dirt [26]. Additionally, the differences between the volunteer groups were not statistically significant. However, in our study, there was a difference in the perception of when washing should be completed: 61.6% when it was covered with foreign substances, such as soot; 31.0% when the FPS smelled burned and 7% after every fire was extinguished ($p < 0.0001$). In addition, career firefighters average monthly routine cleaning frequency was 37%, less than six times a month and after each use and 5% more than seven times a month, while 11% said they did not do so [26]. The differences between volunteer groups were not statistically significant. In our study, the average monthly number of washes was 1 to 2 times for 68.1%, 3 to 4 times for 22.2%, 7 or more times for 5.0% and 5 to 6 times for 4.7% ($p < 0.0001$).

In this study, researchers confirmed that individual firefighters' public health awareness of occupational exposure risks influences their right thinking to prevent cross-contamination inside a fire vehicle by removing the FPS before boarding the fire vehicle in situations where they must take off their FPS after a fire. (AOR 1.97. 95% CI 1.02–3.80). However, there was no statistically significant difference between the desirable behaviors of firefighters taking off their firefighting suits and boarding fire trucks. That is, there was an association between firefighters' public health awareness of occupational exposure and the use of FPSs and a correlation between behavior and the correct use of FPSs (AOR 1.49, 95% CI 0.48–4.59) and washing behavior (AOR 2.50, 95% CI 0.93–6.68) and management behavior (AOR 1.38, 95% CI 0.75–2.50).

4.3. Efforts, Interventions and Implications for Practicing Occupational Health Behaviors to Prevent Occupational Diseases among Firefighters

Many pollutants generated at disaster sites, including fires, are associated with chronic health outcomes, such as cancer [23,38–41]. The emergency decontamination of PPE is very important for firefighters because the dust generated at disaster sites, such as fires, can be absorbed through the respiratory system and skin [23]. However, our study confirmed that removing PPE, such as an FPS, before returning after completing on-scene firefighting activities was almost nonexistent. Additionally, awareness of occupational exposure risks that influenced thoughts of safe FPS use was confirmed but did not affect behavior. Therefore, interventions are needed to increase the awareness of occupational exposure to various disaster sites and practice desirable behaviors. Currently, no training course exists for health and safety training on occupational exposure risks for firefighters in service except for those as incident safety officers. Even though there is a one-time training, repeat training is not provided. Additionally, there is no health and safety education on occupational exposure risks even in the training course conducted for six months after being hired as a firefighter. Therefore, to ensure firefighters' right to health, it is necessary for hired firefighters to receive training in occupational exposure risks before exposure to a fire. Furthermore, it is crucial to establish a mechanism to assist civil servants, particularly firefighters, in practicing health and safety measures independently by providing education on occupational health and safety regarding occupational exposure risks throughout their career lifecycle. Epidemiological data suggest that firefighters have a higher risk of skin cancer during fire response activities due to the dermal absorption of carcinogenic compounds or harmful chemicals found in PAH, which are formed as by-products of the combustion of materials during fires. It has been indicated that the PPE used by firefighters may favor dermal absorption and increase the risk of cancer. Therefore, it is imperative to establish a mechanism that offers ongoing education on occupational health and safety to enable civil servants to practice health and safety measures on their own [29].

4.4. Guide to Personal Protective Equipment for Firefighter Health and Fire Station Construction

Firefighters who respond to various scenes, such as fires, collapses, explosions, traffic accidents, earthquakes, typhoons, heavy floods and water accidents, are repeatedly exposed

to unpredictable hazardous substances generated at the disaster scene. For this reason, firefighters work with the potential risk and possibility of contracting job-related diseases, such as cancer, acute and chronic lung diseases and water-borne diseases [31,42]. If firefighters do not wear PPE completely at the scene of a water accident, they may ingest water-borne viruses or bacteria contained in the water, and vomiting, diarrhea or pneumonia may occur depending on the individual [43,44]. Firefighters engaged in fire work increase the risk of developing cancer by being continuously and repeatedly exposed to carcinogenic substances. In particular, in the case of some cancers, it has already been confirmed that the cancer incidence rate in firefighters is higher than in the general population. Unlike general workers, it is difficult for firefighters to predict exactly what harmful factors are present at the work site to which they are dispatched, which is one of the factors threatening health and safety. Therefore, it is very important for firefighters to thoroughly use and manage PPE to protect themselves from various hazardous substances. However, as shown in the results of this study, the problem was identified that although firefighters have ideas about the proper use of FPSs, they do not take the correct action. The research results on the use, washing and management of FPSs are very important findings in terms of disease prevention for firefighters. Therefore, based on the results of this study, we propose the following items for systematic disease prevention and the health promotion of firefighters;

(1) It is specified in the relevant regulations that emergency decontamination using water be carried out on scene after the firefighting activity is completed. However, because there is a risk that hazardous substances may penetrate into the FPS and be absorbed into the skin, never use an air gun to remove hazardous substances from the FPS.
(2) Equipment that is heavily contaminated at the fire scene should be scrubbed and cleaned on site.
(3) After completing firefighting activities and before leaving for the fire station, place the contaminated equipment in a bag, seal it and then board the firefighting vehicle.
(4) Persons in charge of administrative departments purchase and supply decontamination supplies for emergency decontamination at fire sites.
(5) The relevant regulations specify that the secondary decontamination of the entire body is carried out after firefighters return to the fire station.
(6) To prevent the skin absorption of hazardous substances exposed during the process of taking off the FPS or at the scene of firefighting activities, firefighters who have been dispatched must be educated and instructed that occupational exposure can be reduced by taking a full-body shower within one hour after returning to the fire station.
(7) Upon returning to the fire station, firefighters wash contaminated equipment used at the firefighting scene.
(8) Contaminated equipment must be stored in a protective case when stored or moved in a vehicle owned by the owner.
(9) Repeated training on the safety management manual for special FPS should be provided to firefighters in charge of fire work and encourage them to practice appropriate use, washing and management behavior.
(10) In the case of fire departments with many fire dispatches, relatively extra FPSs are needed for emergency decontamination and the cleaning of contaminated equipment, so the reserve rate should be increased by securing the budget.
(11) At the architectural design stage within the fire station, the spatial configuration and dispatch route must be designed separately to prevent the inflow of hazardous substances into the fire station (Hot zone, Warm zone, Cold zone).

4.5. Strength, Limitations and Further Study

Researchers studied the association between the characteristics of FPSs worn by firefighters and their health awareness of occupational exposure risks. Prior research has been conducted on the associations between FPS decontamination behavior, effectiveness, cleaning, designs and health beliefs. However, this study is meaningful, as there is little

prior research on the association between the characteristics of FPSs and the perception of occupational exposure risks worldwide. Our study also showed a survey participation rate of more than 30% for each fire station among firefighters performing fire suppression duties in large cities, sufficiently reflecting the characteristics of large city firefighters. Thus, the research results can be generalized without bias. However, because the results were not from a nationwide survey, they are not representative of Korea; therefore, future research is needed. Additionally, the survey included questions about correct thoughts about the use of FPSs and did not survey correct thoughts about washing and management factors for FPSs. Finally, our study was a cross-sectional study, and the causality between exposure and outcome factors could not be confirmed.

5. Conclusions

This study conducted a survey targeting firefighters who perform fire suppression and rescue duties to evaluate the association between their recognition and behaviors regarding FPS use, washing and management and their public health awareness of occupational exposure risks and health. Awareness of the possibility of carcinogens occurring at disaster sites is high (90.9%). There is a connection between these health-related recognition and thoughts about proper FPS use at fire scenes to ensure one's own safety (AOR 1.97. 95% CI 1.02–3.80). However, no association was found between occupational exposure risk health awareness and correct FPS use (AOR 1.49, 95% CI 0.48–4.59), washing (AOR 2.50, 95% CI 0.93–6.68) and management (AOR 1.38, 95% CI 0.75–2.50). Therefore, an intervention program that can implement desirable behaviors based on correct thinking is necessary. Interventions include providing health and safety education to firefighters to make them aware of occupational exposure risks; conducting emergency decontaminations of FPSs on site after firefighting activities are completed to minimize occupational exposure and ensuring the systematic use, washing and management of FPSs. It is necessary to establish and operate a curriculum for each life cycle. This study is very important because it provides data that can help firefighters to proactively prevent occupational diseases by raising occupational health awareness that hazardous substances generated at the dispatch site and chemical hazardous substances contained in FPSs can affect health. Finally, this study can be used to develop a firefighter occupational health curriculum and establish health and safety plans from a mid- to long-term perspective to help firefighters protect themselves from occupational exposure risks and lead healthy and safe occupational lives.

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Informed Consent Statement: Informed consent was obtained from all participants in the study.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

Abbreviation	Explanation
PAH	polycyclic aromatic hydrocarbons
VOC	volatile organic compounds
PPE	personal protective equipment
FPS	firefighting protective suits
SCBA	self-contained breathing apparatus
PFAS	per-and polyfluorinated substances
KFFS	Korean Firefighter's FPS Survey
KFI	Korea Fire Institute
NFPA	National Fire Protection Association
EN	Europe's European
ISO	International Organization of Standardization
ORs	odds ratios
AORs	adjusted odds ratios
CI	confidence intervals
HL	Hosmer–Lemeshow
AG	awareness group
OER	occupational exposure risk
IARC	International Agency for Research on Cancer
SOPs	standard operation procedures
UK	United Kingdom

Appendix A. Characteristics of Using FPSs

Characteristic	N	%	*p*-Value
The experience of not wearing jumper and pants of fire suits at the fire scene			
Yes	98	8.9	<0.0001
No	999	91.1	
Place of FPS are taken off after cleaning up the fire scene			
Fire scene before riding in a fire engine	77	9.1	<0.0001
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 FPS are ideal to wear			
Fire scene before riding in a fire engine	353	33.0	<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 FPS before boarding fire engine after fire activities at fire scene			
Yes	452	41.2	<0.0001
No	645	58.8	
Experiences in riding fire engine after fire activities at fire scene, storing FPS separately			
Yes	165	15.0	<0.0001
No	932	85.0	
How to bring FPS after fire activities at fire scene			
Come in with one's turnout gear	335	35.7	<0.0001
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	
Other	48	5.1	
Total	1097	100.0	

FPS; firefighting protective suits.

Appendix B. Characteristics of Washing FPSs

Characteristic	N	%	*p*-Value
Main washing methods of FPS			
Turnout gear washing machine	827	76.1	<0.0001
Washing machine	195	18.0	
Hand washing	60	5.5	
Others	4	0.4	
Satisfaction with cleanliness after washing			
Very satisfied	49	4.5	<0.0001
Satisfied	299	27.3	
Normal	504	45.9	
Not satisfied	190	17.3	
Absolutely not satisfied	55	5.0	
Monthly average number of FPS washed			
1–2	747	68.1	<0.0001
3–4	244	22.2	
5–6	51	4.7	
Over 7	55	5.0	
Status of separate laundry of FPS inside and outside			
Always	634	57.8	<0.0001
Often	220	20.1	
Normal	99	9.0	
Not often	96	8.7	
Not at all	48	4.4	
FPS washing point			
After each fire	75	7.0	<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	
Status of wearing after FPS used at fire scene			
Always	198	18.1	<0.0001
Often	295	26.9	
Normal	315	28.7	
Not often	251	22.9	
Not at all	38	3.5	
Types of laundry detergents for FPS			
General neutral detergent	590	55.0	<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	1097	100	

FPS; firefighting protective suits.

Appendix C. Characteristics of Management of FPSs

Characteristic	N	%	*p*-Value
How to store FPS			
On the hanger	215	19.8	<0.0001
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 FPS			
Yes	474	43.2	<0.0001
No	623	56.8	
Recognition of methods of use, storage, laundry of FPS			
Very knowing	56	5.1	<0.0001
Knowing	235	21.4	
Normal	571	52.1	
Do not known	215	19.6	
Absolutely not known	20	1.8	
Total	1097	100	

FPS; firefighting protective suits.

References

1. Keir, J.L.A.; Akhtar, U.S.; Matschke, D.M.J.; White, P.A.; Kirkham, T.L.; Chan, H.M.; Blais, J.M. Polycyclic aromatic hydrocarbon (PAH) and metal contamination of air and surfaces exposed to combustion emissions during emergency fire suppression: Implications for firefighters' exposures. *Sci. Total Environ.* **2020**, *698*, 134211. [CrossRef]
2. Fent, K.W.; Eisenberg, J.; Snawder, J.; Sammons, D.; Pleil, J.D.; Stiegel, M.A.; Mueller, C.; Horn, G.P.; Dalton, J. Systemic exposure to PAHs and benzene in firefighters suppressing controlled structure fires. *Ann. Occup. Hyg.* **2014**, *58*, 830–845. [CrossRef]
3. Fent, K.W.; Toennis, C.; Sammons, D.; Robertson, S.; Bertke, S.; Calafat, A.M.; Pleil, J.D.; Wallace, M.A.G.; Kerber, S.; Smith, D.; et al. Firefighters' absorption of PAHs and VOCs during controlled residential fires by job assignment and fire attack tactic. *J. Expo. Sci. Environ. Epidemiol.* **2020**, *30*, 338–349. [CrossRef]
4. Barnard, R.J.; Weber, J.S. Carbon monoxide: A hazard to fire fighters. *Arch. Environ. Health* **1979**, *34*, 255–257. [CrossRef]
5. Na, K.; Cocker, D.R. Fine organic particle, formaldehyde, acetaldehyde concentrations under and after the influence of fire activity in the atmosphere of Riverside, California. *Environ. Res.* **2008**, *108*, 7–14. [CrossRef]
6. Fernandez-Marcos, M.L. Potentially Toxic Substances and Associated Risks in Soils Affected by Wildfires: A Review. *Toxics* **2022**, *10*, 31. [CrossRef]
7. Kirk, K.M.; Splawinski, Z.; Bott, R.C.; Logan, M.B. Combustion products generated in simulated industrial fires. *J. Occup. Environ. Hyg.* **2021**, *18*, 510–521. [CrossRef]
8. Mallah, M.A.; Changxing, L.; Mallah, M.A.; Noreen, S.; Liu, Y.; Saeed, M.; Xi, H.; Ahmed, B.; Feng, F.; Mirjat, A.A.; et al. Polycyclic aromatic hydrocarbon and its effects on human health: An overeview. *Chemosphere* **2022**, *296*, 133948. [CrossRef]
9. Fent, K.W.; Mayer, A.C.; Toennis, C.; Sammons, D.; Robertson, S.; Chen, I.C.; Bhandari, D.; Blount, B.C.; Kerber, S.; Smith, D.L.; et al. Firefighters' urinary concentrations of VOC metabolites after controlled-residential and training fire responses. *Int. J. Hyg. Environ. Health* **2022**, *242*, 113969. [CrossRef] [PubMed]
10. Yuan, Y.; Wu, Y.; Zhao, H.; Ren, J.; Su, W.; Kou, Y.; Wang, Q.; Cheng, J.; Tong, Z. Tropospheric formaldehyde levels infer ambient formaldehyde-induced brain diseases and global burden in China, 2013–2019. *Sci. Total Environ.* **2023**, *883*, 163553. [CrossRef] [PubMed]
11. IARC Monographs on the Identification of Carcinogenic Hazards to Humans. In *Occupational Exposure as a Firefighter*; International Agency for Research on Cancer: Lyon, FR, USA, 2023.
12. Taeger, D.; Koslitz, S.; Käfferlein, H.U.; Pelzl, T.; Heinrich, B.; Breuer, D.; Weiss, T.; Harth, V.; Behrens, T.; Brüning, T. Exposure to polycyclic aromatic hydrocarbons assessed by biomonitoring of firefighters during fire operations in Germany. *Int. J. Hyg. Environ. Health* **2023**, *248*, 114110. [CrossRef]
13. Golka, K.; Weistenhöfer, W. Fire fighters, combustion products, and urothelial cancer. *J. Toxicol. Environ. Health. Part B Crit. Rev.* **2008**, *11*, 32–44. [CrossRef]
14. Hwang, J.; Xu, C.; Agnew, R.J.; Clifton, S.; Malone, T.R. Health risks of structural firefighters from exposure to polycyclic aromatic hydrocarbons: A systematic review and meta-analysis. *Int. J. Environ. Res. Public Health* **2021**, *18*, 4209. [CrossRef]
15. Crawford, J.O.; Winski, T.; McElvenny, D.; Graveling, R.; Dixon, K. Firefighters and cancer: The epidemiological evidence. In *Institute of Occupatioan Medicine Research Report*; Institute of Occupational Medicine: Edinburgh, UK, 2017; pp. 1–10.
16. Lesniak, A.Y.; Bergstrom, H.C.; Clasey, J.L.; Stromberg, A.J.; Abel, M.G. The Effect of Personal Protective Equipment on Firefighter Occupational Performance. *J. Strength Cond. Res.* **2020**, *34*, 2165–2172. [CrossRef] [PubMed]

17. Ramezanifar, S.; Shakiba, Z.; Pirposhteh, E.A.; Poursadeghiyan, M.; Sahlabadi, A.S. The effects of personal protective equipment on heart rate, oxygen consumption and body temperature of firefighters: A systematic review. *Work* **2023**, *76*, 95–107. [CrossRef] [PubMed]
18. Carballo-Leyenda, B.; Gutiérrez-Arroyo, J.; García-Heras, F.; Sánchez-Collado, P.; Villa-Vicente, J.G.; Rodríguez-Marroyo, J.A. Influence of Personal Protective Equipment on Wildland Firefighters' Physiological Response and Performance during the Pack Test. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5050. [CrossRef] [PubMed]
19. Asif, M.; Kala, C.; Gilani, S.J.; Imam, S.S.; Taleuzzaman, M.; Alshehri, S.; Khan, N.A. Protective clothing for firefighters and rescue workers. In *Protective Textiles from Natural Resources*; Elsevier: Amsterdam, The Netherlands, 2022; pp. 611–647.
20. Polanczyk, A.; Piechota-Polanczyk, A.; Dmochowska, A.; Majder-Lopatka, M.; Salamonowicz, Z. Analysis of the effectiveness of decontamination fluids on the level of biological contamination of firefighter suits. *Int. J. Environ. Res. Public Health* **2020**, *17*, 2815. [CrossRef]
21. Stolpman, D.; Williams, D.N.; Solouki, T.; Harris, D.D. Decontamination of metals from firefighter turnout gear. *J. Occup. Environ. Hyg.* **2022**, *19*, 79–86. [CrossRef] [PubMed]
22. Kim, S.J.; Lee, J.-Y.; Hong, J.-H.; Ham, S.J.W. Characteristics of Hazardous Substances Extracted from Laundry Water for Fire Protection Suit Exposed to Fire. *Water* **2022**, *14*, 2383. [CrossRef]
23. Fent, K.W.; Alexander, B.; Roberts, J.; Robertson, S.; Toennis, C.; Sammons, D.; Bertke, S.; Kerber, S.; Smith, D.; Horn, G. Contamination of firefighter personal protective equipment and skin and the effectiveness of decontamination procedures. *J. Occup. Environ. Hyg.* **2017**, *14*, 801–814. [CrossRef]
24. Fernandez, A.R.; Treichel, A.; Myers, J.B.; Bourn, S.S.; Crowe, R.P.; Gardner, B. Evaluating Firefighter On-Scene Decontamination Practices Using a National Fire Records Management System. *J. Occup. Environ. Med.* **2023**, *65*, 931–936. [CrossRef] [PubMed]
25. Macy, G.B.; Hwang, J.; Taylor, R.; Golla, V.; Cann, C.; Gates, B. Examining Behaviors Related to Retirement, Cleaning, and Storage of Turnout Gear Among Rural Firefighters. *Workplace Health Saf.* **2020**, *68*, 129–138. [CrossRef] [PubMed]
26. Hwang, J.; Taylor, R.; Macy, G.; Cann, C.M.; Golla, V. Comparison of Use, Storage, and Cleaning Practices for Personal Protective Equipment Between Career and Volunteer Firefighters in Northwestern Kenkucky in the United States. *J. Environ. Health* **2019**, *82*, 8–15.
27. Oh, H.; Kim, S.; Woo, H.; Ham, S. Associations between Awareness of the Risk of Exposure to Pollutants Occurring at Fire Scenes and Health Beliefs among Metropolitan Firefighters in the Republic of Korea. *Int. J. Environ. Res. Public Health* **2022**, *19*, 8860. [CrossRef] [PubMed]
28. Park, H.S.; Ham, S.; Jeong, J.H.; Kim, S.J.; Woo, H. Examination of Factors Influencing SCBA Washing Behavior among Firefighters in Metropolitan. *Int. J. Environ. Res. Public Health* **2022**, *19*, 2240. [CrossRef] [PubMed]
29. Andrew, C.; Maizel, A.T.; Tighe, M.; Veras, S.E.; Rodowa, A.E.; Falkenstein-Smith, R.; Benner, B.; Hoffman, K.; Donnelly, M.; Hernandez, O.; et al. *Wear and Tear May Cause Firefighter Gear to Release More 'Forever Chemicals'*; NIST: Washington, DC, USA, 2024.
30. Wolffe, T.A.; Robinson, A.; Dickens, K.; Turrell, L.; Clinton, A.; Maritan-Thomson, D.; Joshi, M.; Stec, A.A. Cancer incidence amongst UK firefighters. *Sci. Rep.* **2022**, *12*, 22072. [CrossRef] [PubMed]
31. DeBono, N.L.; Daniels, R.D.; Freeman, L.E.B.; Graber, J.M.; Hansen, J.; Teras, L.R.; Driscoll, T.; Kjaerheim, K.; Demers, P.A.; Glass, D.C.; et al. Firefighting and cancer: A meta-analysis of cohort studies in the context of cancer hazard identification. *Saf. Health Work.* **2023**, *14*, 141–152. [CrossRef] [PubMed]
32. Jahnke, S.A.; Jitnarin, N.; Haddock, C.K.; Kaipust, C.; Poston, W.S.C.; Hollerbach, B.S.; Crisp, C.; Metoyer, B.N. Meta-Analysis of Incidence and Mortality of Firefighter Cancer: An Update on Emerging Science. *Asian Pac. J. Cancer Prev.* **2024**, *25*, 801–811. [CrossRef]
33. NFA. *Act on Management of Firefighting Equipment*; Prime Minister Decree No. 1105; NFA: Red Bank, NJ, USA, 19 November 2014.
34. Group, I.W. Painting, firefighting, and shiftwork. *IARC Monogr. Eval. Carcinog. Risks Hum.* **2010**, *98*, 9–764.
35. Savvidis, C.; Koutsilieris, M. Circadian rhythm disruption in cancer biology. *Mol. Med.* **2012**, *18*, 1249–1260. [CrossRef]
36. Demers, P.A.; DeMarini, D.M.; Fent, K.W.; Glass, D.C.; Hansen, J.; Adetona, O.; Andersen, M.H.; Freeman, L.E.B.; Caban-Martinez, A.J.; Daniels, R.D. Carcinogenicity of occupational exposure as a firefighter. *Lancet Oncol.* **2022**, *23*, 985–986. [CrossRef] [PubMed]
37. Straif, K.; Baan, R.; Grosse, Y.; Secretan, B.; El Ghissassi, F.; Bouvard, V.; Altieri, A.; Benbrahim-Tallaa, L.; Cogliano, V.; WHO International Agency For Research on Cancer Monograph Working Group. Carcinogenicity of shift-work, painting, and fire-fighting. *Lancet Oncol.* **2007**, *8*, 1065–1066. [CrossRef] [PubMed]
38. Wolffe, T.A.M.; Turrell, L.; Robinson, A.; Dickens, K.; Clinton, A.; Maritan-Thomson, D.; Stec, A.A. Culture and awareness of occupational health risks amongst UK firefighters. *Sci. Rep.* **2023**, *13*, 97. [CrossRef] [PubMed]
39. Stec, A.A.; Dickens, K.E.; Salden, M.; Hewitt, F.E.; Watts, D.P.; Houldsworth, P.E.; Martin, F.L. Occupational Exposure to Polycyclic Aromatic Hydrocarbons and Elevated Cancer Incidence in Firefighters. *Sci. Rep.* **2018**, *8*, 2476. [CrossRef] [PubMed]
40. Fent, K.W.; LaGuardia, M.; Luellen, D.; McCormick, S.; Mayer, A.; Chen, I.C.; Kerber, S.; Smith, D.; Horn, G.P. Flame retardants, dioxins, and furans in air and on firefighters' protective ensembles during controlled residential firefighting. *Environ. Int.* **2020**, *140*, 105756. [CrossRef] [PubMed]
41. Brinchmann, B.C.; Bugge, M.D.; Nordby, K.C.; Alfonso, J.H. Firefighting and melanoma, epidemiological and toxicological associations: A case report. *Occup. Med.* **2022**, *72*, 142–144. [CrossRef]

42. Cuenca-Lozano, M.F.; Ramírez-García, C.O. Occupational hazards in firefighting: Systematic literature review. *Saf. Health Work.* **2023**, *14*, 1–9. [CrossRef] [PubMed]
43. Kim, S.J.; Ham, S.J.F. Evaluation of Air Quality inside Self-Contained Breathing Apparatus Used by Firefighters. *Fire* **2023**, *6*, 347. [CrossRef]
44. Kim, J.A.; Song, S.Y.; Jeong, W.; Jun, J.K. Non-cancer health risks in firefighters: A systematic review. *Epidemiol. Health* **2022**, *44*, e2022109. [CrossRef]