

Research Article



# Pregnancy, childbirth, and puerperium outcomes in female firefighters in Korea

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Abbreviations

CI: confidence interval; EMS: emergency medical services; FS: fire suppression; ICD-10: 10th revision of the International Statistical Classification of Diseases and Related Health Problems; NEMA: National Emergency Management Agency; NHICD: National Health Insurance Claim Data; OR: odds ratio; PCPO: puerperium outcome; RRN: resident registration number; SAR: standardized admission ratio; SD: standard deviation.

## ABSTRACT

**Background:** Female firefighters are exposed to hazardous environmental (chemical and physical) and working (shift work, psychological, and ergonomic factors) conditions that have reported or are suspected of adverse effects on reproductive health. However, no previous studies have reported on pregnancy, childbirth, and puerperium outcomes (PCPOs) in female firefighters.

**Methods:** The present study compared hospital admissions for PCPOs, based on 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) codes, among Korean female firefighters with those of the general Korean population. Standardized admission ratios (SARs) and their 95% confidence intervals (CIs) were calculated.

**Results:** The study population included 1,766 female firefighters. Total follow-up duration was 9,659 person-years. Compared to the general female population, the female firefighters' SARs were higher in all admissions for PCPOs (SAR, 1.92; 95% CI: 1.79–2.05); pregnancy and abortive outcomes (SAR, 1.56; 95% CI: 1.12–2.12); other maternal disorders predominantly related to pregnancy (SAR, 2.65; 95% CI: 1.99–3.46); maternal care related to the fetus, amniotic cavity, and possible delivery problems (SAR, 2.13; 95% CI: 1.74–2.57); labor and delivery complications (SAR, 1.55; 95% CI: 1.15–2.06); delivery (SAR, 1.94; 95% CI: 1.80–2.08); and complications predominantly related to puerperium (SAR, 4.68; 95% CI: 2.02–9.23).

**Conclusion:** The results of this study showed high SARs in all and specific subcategories of PCPOs in female firefighters.

**Keywords:** Pregnancy and puerperium outcomes; Reproductive health; Female; Firefighters

## BACKGROUND

The number of women in the workforce is increasing worldwide [1], and a considerable percentage of women are of reproductive age [2,3]. Women aged 25 to 54 years have increased their participation in the labor force in most regions, while participation of men in the same age group has remained stable or has slightly declined across many regions [3]. Sometimes, people are exposed to various reproductive risk factors, such as toxic chemicals, radiation, and intense heat in their workplace without being aware [4]. Occupational exposures to such factors are

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**Competing interests**

The authors declare that they have no competing interests.

**Availability of data and materials**

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**Authors contributions**

Conceptualization: Park J, Kim MG; Data curation: Ahn YS; Formal analysis: Park J, Kim MG; Investigation: Park J, Ahn YS, Kim MG; Writing - original draft: Park J, Kim MG; Writing - review & editing: Park J, Ahn YS, Kim MG.

more likely than environmental exposures [4]. Therefore, it is important to determine factors associated with occupational exposure to hazards that can cause reproductive disorders [4].

Firefighters are engaged in fire suppression (FS) as well as in emergency medical services (EMS) and rescue [5]. The firefighting service is a unique work environment wherein all classes of reproductive hazards may be found [6]. The potential hazards also faced by pregnant female firefighters and the number of female firefighters in Korea has steadily increased from 6.34% in 2013 to 7.54% in 2017 [7,8]. Firefighters are exposed to various dangers including heat, noise, chemicals, poisonous gasses, smoke, carbon monoxide, and diesel fumes [5,9,10]. Among the chemical dangers, exposure to lead, mercury, 2-bromopropane, organic solvents, ethylene glycol, and toluene has been reported to have adverse effects on the female reproductive system [4]. Furthermore, firefighters are exposed to traumatic accidents and job stress and may develop mental disorders, such as post-traumatic stress disorder, as well as suicidal thoughts and behavior, and fetal loss seems to expose women to a higher risk for mental disorders [5,11-13]. Moreover, physically demanding work, standing, walking, lifting and carrying, physical exertion, and non-ergonomic and demanding postures during pregnancy may increase a woman's risk of preterm delivery [14,15]. Finally, shift work has been associated with an increased risk of irregular menstrual cycles, endometriosis, abortion, low birth weight, preterm delivery, and reduced incidence of breastfeeding [15,16].

While a considerable number of firefighters of childbearing age worldwide are exposed to reproductive hazards, there are no known reports on pregnancy, childbirth, and puerperium outcomes (PCPOs) among female firefighters. The aim of this study was to clarify the adverse effects on the reproductive health of female firefighters. In the present study, we compared hospital admissions for PCPOs among Korean female firefighters with those among age-matched women in the general South Korean population.

## METHODS

### Sample and setting

A total of 1,766 female firefighters aged < 45 years (childbearing age) at the start of the study and employed by the Korean National Emergency Management Agency (NEMA) during the study period (from January 1, 2000 to December 31, 2008) were enrolled and fully investigated.

### Data collection and cohort definition

For each female firefighter, the study follow-up period started on either the first day of employment or January 1, 2000, whichever occurred later, and ended on the day of employment termination or December 31, 2008, whichever occurred first. We used a 1-month minimum work duration criterion to determine whether a firefighter worked at one of the four job types within the study period. NEMA provided each worker's name, resident registration number (RRN; a unique 13-digit number assigned to all South Korean individuals), birth date, dates of hire and termination of employment, and individual work histories within 4 job types (FS, EMS, office, and communication). During the cohort, female firefighters were surveyed according to their job period. Many Korean firefighters employed by NEMA are cross-trained and work in multiple job roles that depend on the nature of the emergency; moreover, a firefighter can perform multiple job types simultaneously. Therefore, each firefighter could have work histories that include up to four job types in this study.

### Data sources

Korean National Health Insurance Claim Data (NHICD) were used to obtain records of hospitalization admissions due to PCPOs during the study period. NHICD contains RRN, admission and discharge dates, and reproductive disorder diagnoses categorized using the World Health Organization's 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) classification system. The RRN of an individual was matched to the RRN in the NHICD to determine each individual's reproductive disorder-related hospitalization period. Most hospitalizations were registered in the NHICD because the Korea National Health Insurance Service had covered all South Korean residents since 1989. In this study, we analyzed ICD-10 code O00–O99 [17], which covers admissions related to PCPOs. This disease code includes several ICD-10 subclass codes including pregnancy and abortive outcomes (O00–O08); other maternal disorders predominantly related to pregnancy (O20–O29); maternal care related to the fetus, amniotic cavity, and possible delivery problems (O30–O48); complications of labor and delivery (O60–O75); delivery (O80–O84); complications predominantly related to puerperium (O85–O92); and other obstetric conditions not elsewhere classified (O94–O99).

Members of the reference population, comprising approximately 2% of the South Korean female population, were randomly selected after adjusting for region and age from the NHICD 2000 database. Individual hospital admission records were followed from 2000 to 2008 using the NHICD database.

### Statistical methods

The chi-square and T-test were used to describe the work-related characteristics of female firefighters (**Table 1**). The standardized admission ratios (SARs) were calculated by dividing the recorded number of reproductive disorder-related admissions (i.e., ICD-10 O00–O99 or its subclasses) which occurred between January 1, 2000 and December 31, 2008 in the female firefighter cohort by the recorded number of reproductive disorder-related admissions in the reference population during the same period. The two groups were stratified into 6 age groups ( $\leq 20$ , 20–24, 25–29, 30–34, 35–39, and 40–44 years).

The female firefighter cohort was classified by total work duration ( $< 10$  years and  $\geq 10$  years), main job type (FS, EMS, office, and communications) of total work duration, and work duration ( $< 10$  years and  $\geq 10$  years) for each main job types (FS, EMS, and office). The four job types were categorized depending on their job, FS, EMS (including paramedics and rescue), officers (composed of individuals performing administrative work, investigators of fire grounds), and communication (those involved in communication and information system business) [18].

Because no female firefighter worked in communications for  $> 10$  years, the SARs for work duration ( $< 10$  years and  $\geq 10$  years) for communications were not analyzed. Multiple hospital admissions of the same patient for the same reproductive disorder category subclass were considered a single admission. Multiple admissions of the same patient for different PCPOs category subclasses were regarded as separate admissions. The same principles regarding the number of admissions were applied to both the female firefighter cohort and reference population. Inpatient person-year calculations only included hospital admissions occurring after entry into the firefighter cohort. A minimum of five cases of subcategory admission were analyzed to ensure statistical power (**Tables 2–4**).

**Table 1.** Work-related characteristics of female firefighters (n = 1,766)

Characteristic	Value
Age in 2000 (years)	24.04 ± 5.92
< 20	486 (27.5)
20–24	705 (39.9)
25–29	274 (15.5)
30–34	181 (10.2)
35–39	91 (5.2)
40–44	29 (1.6)
Age at first employment (years)	25.57 ± 3.20
< 20	42 (2.5)
20–24	799 (45.2)
25–29	758 (42.9)
≥ 30	167 (9.5)
Duration of employment (years)	7.15 ± 5.82
< 10	1,344 (76.1)
≥ 10	422 (23.9)
Worked in fire suppression service, n (%)	
No	1,035 (58.6)
Yes	731 (41.4)
Worked in emergency medical service	
No	816 (46.2)
Yes	950 (53.8)
Worked at the office	
None	1,203 (68.1)
Yes	563 (31.9)
Worked in the communications section	
No	1,564 (88.6)
Yes	202 (11.4)
Employment status at the end of study	
On duty	1,648 (93.3)
Retired or dead	118 (6.7)

Values are expressed as mean ± standard deviation or number (%).

SAR and its 95% confidence interval (CI) were calculated using previously developed person-year and mortality computation software [19]. This software allowed objective comparisons of the observed number of admissions among female firefighters with the number of admissions of women of similar ages in the general population. The resulting ratio indicates the increase or decrease in admissions in firefighters compared to the number of admissions in the general population. The use of such data precludes the ability to control for confounding factors, such as smoking, alcohol use, and exercise.

**Table 2.** Standardized admission ratios for pregnancy, childbirth, and puerperium outcomes in female firefighters by work duration compared with those in the general Korean population

Reason for admission <sup>d</sup>	Work duration < 10 years <sup>a</sup>		Work duration ≥ 10 years <sup>b</sup>		Total <sup>c</sup>	
	No.	SAR (95% CI)	No.	SAR (95% CI)	No.	SAR (95% CI)
Pregnancy, childbirth, and puerperium outcomes (O00–O99)	620	1.49 (1.37–1.61) <sup>e</sup>	189	1.96 (1.69–2.26) <sup>e</sup>	809	1.57 (1.47–1.69) <sup>e</sup>
Pregnancy and abortive outcomes (O00–O08)	28	1.42 (0.94–2.05)	13	2.01 (1.07–3.44) <sup>e</sup>	41	1.56 (1.12–2.12) <sup>e</sup>
Other maternal disorders predominantly related to pregnancy (O20–O29)	46	2.72 (1.99–3.63) <sup>e</sup>	8	2.32 (0.99–4.56)	54	2.65 (1.99–3.46) <sup>e</sup>
Maternal care related to the fetus, amniotic cavity, and possible delivery problems (O30–O48)	79	1.92 (1.52–2.39) <sup>e</sup>	29	3.30 (2.12–4.55) <sup>e</sup>	108	2.13 (1.76–2.60) <sup>e</sup>
Complications of labor and delivery (O60–O75)	32	1.22 (0.83–1.72)	17	3.25 (1.89–5.21) <sup>e</sup>	49	1.56 (1.15–2.06) <sup>e</sup>
Delivery (O80–O84)	566	1.84 (1.68–1.99) <sup>e</sup>	171	2.40 (2.05–2.78) <sup>e</sup>	737	1.94 (1.80–2.08) <sup>e</sup>
Complications predominantly related to puerperium (O85–O92)	6	4.15 (1.52–9.03) <sup>e</sup>	2	7.65 (0.86–27.64)	8	4.68 (2.02–9.23) <sup>e</sup>
Other obstetric conditions, those not elsewhere classified (O94–O99)	2	1.07 (0.12–3.90)	3	8.06 (1.62–23.55) <sup>e</sup>	5	2.25 (0.72–5.24)

NOTE: The SAR describes the increase or decrease in admissions in the firefighters compared to admissions in the general population.

SAR: standardized admission ratio; CI: confidence interval; ICD-10: 10th revision of the International Statistical Classification of Diseases and Related Health Problems.

<sup>a</sup>Person-years, 5,977; <sup>b</sup>Person-years, 3,682; <sup>c</sup>Person-years, 9,659; <sup>d</sup>Admission diagnoses and the numbers following the admission diagnosis refer to the ICD-10 codes; <sup>e</sup>p-value < 0.05.

**Table 3.** Standardized admission ratios for pregnancy, childbirth, and puerperium outcomes in female firefighters by job type compared with those in the general Korean population

Reason for admission <sup>a</sup>	Job type							
	Fire suppression <sup>a</sup>		Emergency medical service <sup>b</sup>		Communication <sup>d</sup>			
	No.	SAR (95% CI)	No.	SAR (95% CI)	No.	SAR (95% CI)		
Pregnancy, childbirth, and puerperium outcomes (O00–O99)	310	1.80 (1.60–2.01) <sup>f</sup>	481	2.00 (1.82–2.19) <sup>f</sup>	243	1.69 (1.49–1.93) <sup>f</sup>	98	1.94 (1.58–2.37) <sup>f</sup>
Pregnancy and abortive outcomes (O00–O08)	16	1.52 (0.80–2.47)	25	1.67 (1.08–2.47) <sup>f</sup>	14	1.56 (0.86–2.61)	5	1.54 (0.50–3.59)
Other maternal disorders predominantly related to pregnancy (O20–O29)	23	2.73 (1.73–4.09) <sup>f</sup>	30	2.59 (1.74–3.70) <sup>f</sup>	20	2.91 (1.78–4.50) <sup>f</sup>	5	2.10 (0.68–4.91)
Maternal care related to the fetus, amniotic cavity, and possible delivery problems (O30–O48)	33	1.59 (1.09–2.24) <sup>f</sup>	75	2.62 (2.06–3.28) <sup>f</sup>	30	1.71 (1.14–2.45) <sup>f</sup>	5	0.84 (0.27–1.98)
Complications of labor and delivery (O60–O75)	18	1.37 (0.82–2.18)	33	1.84 (1.27–2.59) <sup>f</sup>	11	1.04 (0.52–1.86)	5	1.36 (0.44–3.19)
Delivery (O80–O84)	285	1.82 (1.62–2.05) <sup>f</sup>	435	2.00 (1.81–2.19) <sup>f</sup>	228	1.77 (1.54–2.01) <sup>f</sup>	92	2.03 (1.63–2.49) <sup>f</sup>
Complications predominantly related to puerperium (O85–O92)	1	1.39 (0.02–7.76)	5	5.18 (1.67–12.09) <sup>f</sup>	2	2.66 (0.30–9.61)	0	-
Other obstetric conditions, those not elsewhere classified (O94–O99)	1	1.08 (0.01–6.02)	4	3.16 (0.86–8.07)	2	1.56 (0.86–2.61)	1	3.85 (0.02–21.42)

NOTE: The SAR describes the increase or decrease in admissions in the firefighters compared to admissions in the general population.

SAR: standardized admission ratio; CI: confidence interval; ICD-10: 10th revision of the International Statistical Classification of Diseases and Related Health Problems.

<sup>a</sup>Person-years 3,857; <sup>b</sup>Person-years, 5,336; <sup>c</sup>Person-years, 1,286; <sup>d</sup>Admission diagnoses and the numbers following the admission diagnosis refer to the ICD-10 codes; <sup>f</sup>p-value < 0.05.

**Table 4.** Standard admission ratios for pregnancy, childbirth, and puerperium outcomes in female firefighters by work duration in each job type compared with those in the general Korean population

Reason for admission <sup>a</sup>	Work duration											
	Fire suppression		Emergency medical service		Office							
	No.	SAR (95% CI)	No.	SAR (95% CI)	No.	SAR (95% CI)						
Pregnancy, childbirth, and puerperium outcomes (O00–O99)	251	1.40 (1.23–1.58) <sup>h</sup>	59	1.90 (1.44–2.45) <sup>h</sup>	390	1.55 (1.40–1.71) <sup>h</sup>	91	2.19 (1.77–2.69) <sup>h</sup>	225	1.42 (1.23–1.61) <sup>h</sup>	18	1.23 (0.73–1.95)
Pregnancy and abortive outcomes (O00–O08)	13	2.87 (1.77–4.38) <sup>h</sup>	3	2.69 (0.54–7.86)	18	1.47 (0.87–2.32)	7	2.57 (1.03–5.30) <sup>h</sup>	13	1.65 (0.88–2.82)	1	0.89 (0.02–4.96)
Other maternal disorders predominantly related to pregnancy (O20–O29)	21	2.87 (1.77–4.38) <sup>h</sup>	2	1.79 (0.20–6.48)	27	2.77 (1.76–3.89) <sup>h</sup>	3	2.01 (0.40–5.37)	18	2.84 (1.67–4.48) <sup>h</sup>	2	3.91 (0.44–14.10)
Maternal care related to the fetus, amniotic cavity, and possible delivery problems (O30–O48)	26	1.46 (0.96–2.14)	7	2.37 (0.95–4.88)	59	2.39 (1.82–3.08) <sup>h</sup>	16	4.06 (2.32–6.59) <sup>h</sup>	29	1.86 (1.25–2.67) <sup>h</sup>	1	0.72 (0.01–4.00)
Complications of labor and delivery (O60–O75)	13	1.14 (0.61–1.95)	5	2.97 (0.96–6.92)	23	1.47 (0.93–2.21)	10	4.44 (2.13–8.17) <sup>h</sup>	11	1.12 (0.56–2.00)	0	-
Delivery (O80–O84)	230	1.72 (1.51–1.96) <sup>h</sup>	55	2.39 (1.80–3.11) <sup>h</sup>	355	1.90 (1.71–2.11) <sup>h</sup>	80	2.59 (2.05–3.22) <sup>h</sup>	211	1.79 (1.51–1.96) <sup>h</sup>	17	2.59 (0.93–2.55)
Complications predominantly related to puerperium (O85–O92)	1	1.58 (0.02–8.79)	0	-	4	4.68 (1.26–11.98) <sup>h</sup>	1	9.06 (0.11–50.36)	1	1.86 (0.02–10.35)	1	24.30 (0.32–13.80)
Other obstetric conditions, those not elsewhere classified (O94–O99)	1	1.24 (0.02–6.91)	0	-	2	1.80 (0.20–6.53)	2	12.56 (1.41–45.35) <sup>h</sup>	2	2.87 (0.32–10.37)	0	-

NOTE: The SAR describes the increase or decrease in admissions in the firefighters compared to admissions in the general population.

SAR: standardized admission ratio; CI: confidence interval; ICD-10: 10th revision of the International Statistical Classification of Diseases and Related Health Problems.

<sup>a</sup>Person-years, 2,504; <sup>b</sup>Person-years, 1,353; <sup>c</sup>Person-years, 3,978; <sup>d</sup>Person-years, 1,358; <sup>e</sup>Person-years, 2,682; <sup>f</sup>Admission diagnoses and the numbers following the admission diagnosis refer to the ICD-10 codes; <sup>h</sup>p-value < 0.05.

### Ethics statement

This study was approved by the Dongguk University Ilsan Hospital Institutional Review Board (2009-117). The need for informed consent was waived by the board.

## RESULTS

### Work-related characteristics of female firefighters

The study population included 1,766 female firefighters with a total follow-up period of 9,659 person-years. In 2000, the mean age with standard deviation (SD) of the firefighters was  $24.04 \pm 5.92$  years, whereas their mean age at first employment was  $25.57 \pm 3.20$  years. A total of 486 (27.5%) firefighters aged < 20 years in 2000 were included in this study because they entered childbearing age (20–44 years) during an 8-year follow-up period. Most (76.1%) firefighters had a work duration < 10 years, and the mean duration (with SD) of employment was  $7.15 \pm 6.9$  years. Among the female firefighters, occupation types included FS (41.4%), EMS (53.8%), office (31.9%), and communications (11.4%) during the study period, and during this time only a small number of firefighters (6.7%) died or retired (**Table 1**).

### Hospital admission for PCPOs

Compared to those in the reference population, the SARs for pregnancy and abortive outcomes (SAR, 1.56; 95% CI: 1.12–2.12); other maternal disorders predominantly related to pregnancy (SAR, 2.65; 95% CI: 1.99–3.46); maternal care related to the fetus, amniotic cavity, and possible delivery problems (SAR, 2.13; 95% CI: 1.76–2.60); complications of labor and delivery (SAR, 1.56; 95% CI: 1.15–2.06); delivery (SAR, 1.94; 95% CI: 1.80–2.08); and complications related to postpartum (SAR, 4.68; 95% CI: 2.02–9.23) and for all PCPOs (SAR, 1.57; 95% CI: 1.47–1.69) in female firefighters were significantly higher. SAR for other obstetric conditions, those not elsewhere classified, was not significantly high in the firefighter cohort (SAR, 2.25; 95% CI: 0.75–5.24). Additionally, compared to that in the general population, the SAR for firefighters with a work duration  $\geq 10$  years was significantly higher (**Table 2**).

### Hospital admission for PCPOs by job type

Compared to those in the reference population, the SARs associated with all PCPOs (SAR, 1.80; 95% CI: 1.60–2.01); other maternal disorders predominantly related to pregnancy (SAR, 2.73; 95% CI: 1.73–4.09); maternal care related to the fetus, amniotic cavity, and possible delivery problems (SAR, 1.59; 95% CI: 1.09–2.24); and delivery (SAR, 1.82; 95% CI: 1.62–2.05) in female firefighters working in FS were significantly higher (**Table 3**). Moreover, the SARs for all of PCPOs (SAR, 2.00; 95% CI: 1.82–2.19); pregnancy and abortive outcomes (SAR, 1.67; 95% CI: 1.08–2.47); other maternal disorders predominantly related to pregnancy (SAR, 2.59; 95% CI: 1.74–3.70); maternal care related to the fetus, amniotic cavity, and possible delivery problems (SAR, 2.62; 95% CI: 2.06–3.28); complications of labor and delivery (SAR, 1.84; 95% CI: 1.27–2.59); delivery (SAR, 2.00; 95% CI: 1.82–2.19); and complications predominantly related to postpartum (SAR, 5.18; 95% CI: 1.62–12.09) in female firefighters working in the EMS were significantly high.

Compared to those in the reference population, the SARs for all PCPOs (SAR, 1.69; 95% CI: 1.49–1.93); other maternal disorders predominantly related to pregnancy (SAR, 2.91; 95% CI: 1.78–4.50); maternal care related to the fetus, amniotic cavity, and possible delivery problems (SAR, 1.71; 95% CI: 1.14–2.45); and delivery (SAR, 1.77; 95% CI: 1.54–2.81) in

office-based female firefighters were significantly higher (Table 3). Moreover, the SARs for all PCPOs (SAR, 1.94; 95% CI: 1.58–2.37) and delivery (SAR, 2.03; 95% CI: 1.62–2.49) in female firefighters working in communications were significantly high.

### Hospital admission for PCPOs by work duration in each job type

Compared to those in the reference population, the SARs for all PCPOs (SAR, 1.90; 95% CI: 1.44–2.45) and delivery (SAR, 2.39; 95% CI: 1.80–3.11) in female firefighters working in FS for > 10 years were significantly higher (Table 4). Moreover, the SARs for all PCPOs (SAR, 2.19; 95% CI: 1.77–2.69); pregnancy and abortive outcomes (SAR, 2.57; 95% CI: 1.03–5.30); maternal care related to the fetus, amniotic cavity, and possible delivery problems (SAR, 4.06; 95% CI: 2.32–6.59); complications of labor and delivery (SAR, 4.44; 95% CI: 2.13–8.17); delivery (SAR, 2.59; 95% CI: 2.05–3.22); and other obstetric conditions not elsewhere classified (SAR, 12.56; 95% CI: 1.41–45.35) in female firefighters working in the EMS for > 10 years were significantly high. However, compared to the reference population, there were no significant changes in SAR in female firefighters working in offices for > 10 years. The authors have only described the results for data for  $\geq 10$  years in FS, EMS, and office workers since there were no workers employed in communications for > 10 years (Table 4).

## DISCUSSION

In this study, we found that female firefighters, compared to the Korean general population, showed high SARs in PCPOs. The high SARs in PCPOs was also shown by all job types, especially when they worked in FS and EMS for more than 10 years.

Reproductive risks in women include the effects of shift work and circadian desynchrony, high temperatures, loud noises and physical tension of firefighting, as well as exposure to fire sites and other emergency responses [10,20].

Most South Korean female firefighters are shift workers and, as a group and compared to the reference population, have high SARs associated with PCPOs. Shift work has been associated with an increased risk of irregular menstrual cycles, endometriosis, pregnancy and abortive outcomes, and low birth weight or preterm delivery and reduced incidence of breastfeeding [20,21]. Furthermore, a slight, but not significant, increased risk of pregnancy and abortive outcomes was reported in women working irregular shifts (working at different times of the day and night on a permanent schedule) and rotating shifts (1 of 3 shifts in 24 hours) compared to women who worked only during the day [22]. Moreover, a recent study reported that working fixed night shifts was associated with a moderately increased risk of pregnancy and abortive outcomes, while working a three-shift schedule, working for > 40 hours weekly, lifting > 100 kg/day, standing > 6 hr/day, and having a physical workload were also associated with an increased risk of pregnancy and abortive outcomes [23]. Gaskins et al. [24] reported that working > 40 hours weekly and moving or lifting heavy loads > 15 times per day (including repositioning or transferring patients) were associated with reduced fecundity (i.e., longer median duration of pregnancy attempts) in a cohort of female nurses planning pregnancy.

Female firefighters who have worked in EMS for a long time, although there was no objective standardization of how much work was performed by the firefighters, had a higher SAR related to pregnancy and abortive outcomes, maternal care related to the fetus and amniotic cavity and possible delivery problems, complications of labor and delivery, delivery and

complications predominately related to puerperium than those who worked in other job types. EMS workers, such as ambulance workers, have a higher level of accident-related injuries and a higher standardized early retirement on medical grounds than the general working population and workers in other health-related occupations [25]. Ambulance workers also have more musculoskeletal problems than the general population [25]. Kim et al. [26] reported that EMS activities induce high muscle fatigue and energy consumption, and muscle fatigue accumulates during continued EMS-related work. Moreover, EMS workers are exposed to heavier physical loads than workers in other job types [27]. Although the injury might be more severe in FS compared to EMS, EMS workers were 1.5 times more likely to be injured than FS workers [18]. In women, heavy physical work has been reported to be a risk factor for not only pregnancy and abortive outcomes but also low birth weight and preterm delivery [28]. Moreover, physically demanding work during pregnancy is associated with an increased risk of preterm delivery especially in jobs with a combination of tasks that require physical effort [29]. Luke and Papiernik [30] reported that physical and mental factors, such as fatigue, heavy lifting, standing, and repetitive work may cause stress and lead to the release of catecholamines, which may, in turn, increase blood pressure and uterine contractility and decrease placental function.

During a fire event, firefighters may be exposed to toxic chemical agents, such as acrolein, aldehyde, benzene, carbon dioxide, carbon monoxide, and chloroform [31]. Benzene is the second most common organic constituent measured in fire smoke and may be present at high concentrations [32]. A study of 3,000 women employed in a Chinese petrochemical plant reported an increased risk of pregnancy and abortive outcomes associated with exposure to benzene (odds ratio [OR], 2.5; 95% CI: 1.7–3.7), gasoline (OR, 2.3; 95% CI: 1.1–2.9), and hydrogen sulfide (OR, 2.3; 95% CI: 1.2–4.4) [33]. Moreover, exposure to carbon monoxide and particulate matter  $\leq 10 \mu\text{m}$  in diameter during early and late pregnancy was associated with an increased risk of low birth weight and preterm delivery among women in Los Angeles County, CA, USA [34]. Ahn et al. [35] indicated that there are differences in working conditions for firefighters in FS and other job types that provide medical aid and technical rescue. However, many Korean firefighters employed by NEMA are cross-trained and serve multiple roles that depend on the nature of the emergency [36]. Therefore, during a fire event, all firefighters, except those who are office based, can be exposed to toxic substances [31,35]. In this study, the SAR of PCOPs in all job types according to the length of work were high, but there was a difference in each reproductive disorder subcategory. In addition, how much or long each individual has been exposed to toxic chemical agents is unknown. Determination of the types of chemical exposures and firefighter duties at the time of conception was beyond the scope of this study. Therefore, it is necessary to conduct further research to determine the association between exposures to particular chemical agents among the four types of firefighter duties and PCPOs in pregnant firefighters.

In our study, female firefighters who worked > 10 years in FS and EMS, although those who worked in EMS had a higher SAR related to pregnancy and abortive outcomes, maternal care related to the fetus and amniotic cavity and possible delivery problems, complications of labor and delivery, and other obstetric conditions, and those not elsewhere classified, than those who worked in FS, showed a significantly higher SAR in PCPOs. The adverse pregnancy outcomes were affected by physiological dysregulation due to chronic stress [36]. Firefighters routinely face severe physical and psychological stress and are exposed to physical hazards such as heat and noise [37]. Firefighters who worked for more than 10 years have a higher frequency of injuries than those who have worked for less than 10 years, and work duration



of firefighter influenced the physiologic injury [38,39]. However, there are few related studies of firefighter work duration, chronic stress, and pregnancy outcomes. It is likely that further research in these areas will be needed.

The strengths of our study are as follows: first, the sample size of this study comprised almost all female firefighters in South Korea. Hospital births accounted for 99.8% of deliveries in South Korea [40]. Therefore, changes in home birth rate have not likely affected the result of this study, and the female firefighters in this study can be deemed representative of the general female population in South Korea. Second, this is the first study to compare SARs for PCPOs among firefighters with those of the general population. Lastly, the statistically significantly increased SARs for all PCPOs and various subcategories of PCPOs in firefighters were determined through objective data analysis rather than through the review of subjective questionnaires.

The limitations of this study are as follows: First, our study was based on hospital admission data with no controls for lifestyle factors, such as smoking, alcohol drinking, and exercise, which could affect PCPOs. Second, firefighters have a higher risk of having a child with congenital heart anomaly than police force members [41]. In the present study, we investigated PCPOs in female firefighters but did not obtain data on congenital anomalies or low birth weight. Thus, a detailed study that includes investigation on the associations among congenital anomalies of offspring of firefighters, chemical exposures, and firefighter job type at the time of conception is needed. Third, we could not obtain information on firefighter job type at the time of conception. Therefore, we were unable to elucidate fully the relationships between job types and SARs for all or subcategories of PCPOs. It was not sufficient to obtain more information about pregnancy-related leave, occupations during pregnancy or childbirth, and type of occupation that worked the longest. Fourth, the general population also included people who have no jobs or housewives. Hospital workers who night shift work, such as firefighters, are more likely to get sick during pregnancy as they work longer (OR, 1.37; 95% CI: 1.15–1.63 for nurses) [42]. In addition, there was a high rate of spontaneous abortion among semiconductor workers prior to 2008 in Korea, when there was a high likelihood of exposure to hazardous chemicals such as the case of firefighters (OR, 2.21; 95% CI: 1.01–4.81) [43]. So, it would be necessary to make a comparative analysis with similar occupation groups such as nurses with similar work patterns or workers in the industry exposed to hazardous substances. Finally, even if there are higher SARs associated with delivery than those in the general population, it cannot be determined that SAR may be high in all and specific subcategories of PCPOs among female firefighters. Comparing with groups with similar working environments or prospective studies may be necessary.

## CONCLUSIONS

Despite the limitations, this is the first study on obstetric diseases in female firefighters. The results of this study showed high SARs in all and specific subcategories of PCPOs in female firefighters. There may be a need for a departmental policy-based approach to female firefighters' reproductive health.

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