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Original Article

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Relationship Between Exposure to Second-Hand Smoke in the Workplace and Occupational Injury in the Republic of Korea

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Abstract

Background: Most studies in the field of smoking exposure in the workplace linked to occupational safety have only focused on active smoking. Few studies have reported that exposure to second-hand smoke in the workplace is a possible factor increasing the risk of occupational injury without considering occupational characteristics. The aim of this study was to determine the association between occupational injury and level of exposure to second-hand smoke at the workplace among Korean workers, after taking into account occupational characteristics.

Method: Using data from the third Korean Working Conditions Survey, levels of exposure to second-hand smoke were categorized as none, moderate, and high. We investigated the influence of exposure to second-hand smoke on occupational injury using logistic regression analysis with stratification by sex, smoking status, smoke-free policy in the workplace, and occupational characteristics. Occupational characteristics (occupational classification, working schedule, length of working day, and co-exposure to occupational hazards in the workplace) were stratified and analyzed using logistic regression models to estimate the risk of occupational injury linked to exposure to second-hand smoke.

Results: Among all participants, there was a significant dose-dependent association between risk of occupational injury and level of exposure level to second-hand smoke. After stratification by sex and smoking status, there was a significant association between risk of occupational injury and exposure level to second-hand smoke. Moreover, there was a significant relationship between exposure to second-hand smoke in the workplace and occupational injury, depending on the smoking-free policy at workplace (odds ratio [OR] in completely non-smoking workplace, 4.23; OR in non-smoking workplace with separate smoking area, 2.98; OR in smoking workplace 2.84). Additionally, there was a significant relationship between risk of occupational injury and exposure to second-hand smoke after stratification by occupational classification, working schedule, long working hours, and co-exposure to hazards in the workplace.

Discussion: There was a dose–response relationship between occupational injury and exposure to second-hand smoke, even after stratification to reduce the impact of various potential confounders and after taking into account occupational characteristics. These findings provide greater insight into the effects of exposure to second-hand smoke on the working population and may direct further research and policy-making in this field.

Keywords: environmental tobacco smoke; involuntary smoking; occupational injury; passive smoking; second-hand smoking; tobacco smoke pollution; the Korean Working Conditions Survey

Introduction

Since the release of the US Surgeon General's 1964 Report on Smoking and Health, the adverse health effects of tobacco smoking have been extensively studied (Office of the Surgeon General, 1964). Tobacco use is a preventable cause of mortality and morbidity. It causes serious diseases and disability and is strongly implicated in cancer, diabetes, cardiovascular diseases, and chronic obstructive pulmonary disease (Office of the Surgeon General, 2014). Every year, more than 5 million tobacco smokers die globally, and it is predicted that tobacco use will cause over 8 million deaths by 2030 (WHO, 2009). In 2015, smoking caused >1 in 10 deaths globally, killing 6.4 million people and accounting for ~150 million smoking-attributable disability-adjusted life-years (Marissa *et al.*, 2017)

The risks of exposure to second-hand smoke have been reported since 1928 (Schönherr, 1928). Second-hand smoke, also known as involuntary smoking, passive smoking, and exposure to environmental tobacco smoke, is exposure to smoke emitted from burning tobacco products plus smoke exhaled by smokers (King *et al.*, 2013). Environmental tobacco smoke is a complex mixture of >7000 different chemical compounds, including hundreds that are toxic and ~70 of which are carcinogens (Office of the Surgeon General, 2014). Second-hand smoke has become a considerable risk to human health, resulting in lung cancer, stroke, coronary heart disease, and other harmful diseases in the general population. It leads to the deaths of >40 000 non-smokers, and ~6.6 billion dollars in lost productivity, annually (Office of the Surgeon General, 2006; Prüss-Ustün *et al.*, 2011; Max *et al.*, 2012).

Most people are unaware of the level of exposure to second-hand smoke to which they are exposed from the environment in their daily lives. As environmental tobacco smoke exists in all places where smoking takes place, including homes, public transport, workplaces, and other public areas, it has proved difficult to quantify absolutely the unexposed population (King *et al.*, 2013). Although many countries have enacted tobacco control legislation relating to the workplace and other public areas in order to protect the general population from exposure to environmental tobacco smoke, millions of the general population are still exposed to it (WHO, 2009; CDC, 2010). Workers are particularly vulnerable to exposure to second-hand smoke in the workplace because this is where they usually spend the majority of their time during the day (Office of the Surgeon General, 2006). The International Labor Organization (ILO) and several studies have reported that smoking in the workplace has become a major factor in job-related deaths and a significant health hazard (Siegel and Skeer, 2003; Ho *et al.*, 2007; Stayner *et al.*, 2007). Furthermore, exposure to tobacco smoke may aggravate existing occupational injuries. Numerous studies have reported that job-related injuries and accompanying mortality are significantly higher among smokers than non-smokers; a few studies have also indicated that exposure to second-hand smoke in the workplace is a possible factor increasing the risk of occupational injuries (Leistikow *et al.*, 1998; Wen *et al.*, 2005; Nakata *et al.*, 2006;

Kim *et al.*, 2015). However, the results of previous studies on the association between exposure to second-hand smoke in the workplace and occupational injury among non-smokers have been contradictory and have not considered occupational characteristics that could impact on occupational injury. Moreover, it may not be possible to extrapolate to the general population the results of studies on the association between occupational injury and exposure to second-hand smoke conducted on manual workers only (Nakata *et al.*, 2006; Kim *et al.*, 2015). Further study which considers occupational characteristics is needed in order to better understand the association between exposure to second-hand smoke and occupational injury among workers.

In an attempt to regulate smoking in the workplace, many countries have implemented a total ban on smoking in the workplace or have allowed employers to designate a specific smoking area separate from the workplace so that employees may easily avoid exposure to environmental tobacco smoke (Hyland *et al.*, 2012). However, no study has investigated the relationship between occupational injury and exposure to second-hand smoke in workplaces which operate complete no-smoking policies, those which are non-smoking but have separate smoking areas, and those with no restrictions on smoking.

Therefore, we carried out this study to investigate, among Korean workers, whether occupational injury was associated with both the level of exposure to environmental tobacco smoke and smoke-free policies in the workplace. We took into account various occupational characteristics and used data from a national representative survey, the 2011 third Korean Working Conditions Survey (KWCS), which was performed by the Occupational Safety and Health Research Institute (OSHRI) of Korea.

Methods

Study population

This study was based on data from the KWCS, which was conducted by the OSHRI to better understand types of employment, status of employment, occupational hazards, and the working environment. The research methods and the contents of the KWCS have been benchmarked against the master questionnaire of the European Working Conditions Survey, after accounting for cultural differences (Kim *et al.*, 2015). The survey participants were workers aged over 15 years who were selected from across the country using multistage systematic cluster sampling methods. The survey was conducted during house visits via computer-assisted face-to-face interviews by trained interviewers. All participants provided written informed consent and data were collected anonymously. The quality of the KWCS was assured and deemed reliable and valid (Kim *et al.*, 2013). The KWCS gathered data from 50 032 individuals; we investigated 49 106 participants (28 125 male and 20 981 female workers) and excluded 926 individuals with any incomplete data relating to variables under investigation in the current study.

Smoking-related factors

The KWCS's questions on exposure level to second-hand smoke focused on the workplace. To identify the level of exposure to second-hand smoke in the workplace, we used the question 'Please tell me, using the following scale, if you are exposed at work to tobacco smoke from other people?' Participants answered this question on a 7-point scale (all of the time, almost all of the time, approximately three-quarters of the time, approximately half of the time, approximately one-fourth of the time, almost never, and never). These responses were divided into three categories: none, moderate, and high. Workers who were never exposed to second-hand smoke were categorized as 'none', workers who responded, 'almost never' and 'approximately one-fourth of the time' were categorized as 'moderate', and workers who responded 'approximately half the time' and above were categorized as 'high'. The KWCS also asked participants about smoke-free policies in the workplace, and, from that information, we characterized workplaces as 'completely non-smoking', 'non-smoking with separate smoking area', and 'smoking'.

Occupational characteristics

Subjects were asked the following questions, which were identical to the questions used in the KWCS regarding occupational injury: 'Over the last 12 months, have you suffered from any of the following health problems?' (8 categories including 'injuries'); respondents who answered 'yes' to 'injuries' were then they asked, 'Was your injury related to work?' Those who answered 'yes' were considered to have experienced occupational injury. The occupational characteristics also included important covariates including working schedule (shift or fixed), long working hours (working more than 52 hours per week), and self-rated job satisfaction level (using the question 'On the whole, are you very satisfied, satisfied, not very satisfied, or not at all satisfied with working conditions in your main paid job?'; these responses were then categorized as 'satisfaction' [very satisfied], moderate [satisfied], and dissatisfaction [not very satisfied and not at all satisfied]).

The International Standard Classification of Occupations (ISCO)-08 classifies occupations into 10 major groups. We used Lee *et al.*'s (2016) recategorization of the ISCO into four major groups of workers: 1–3 (white-collar), 4–5 (pink-collar), 6 (green-collar), and 7–9 (blue-collar). Major group 0 (armed forces occupations) of the ISCO was excluded as the Korean policy of compulsory military service for men (aged ~20 to 24 years) for a minimum 20 months might have increased the gender and age heterogeneity of the sample.

Risk of occupational injury can be increased due to co-exposure to occupational hazards. Thus, the KWCS used questionnaires to assess the level of exposure to hazards in the workplace. The questionnaires included various workplace hazards including: vibrations from hand tools, machinery, etc. (vibration); noise so loud that you would have to raise your voice to talk to people (noise); high temperatures which make you perspire even when not working (heat); low temperatures whether indoors or outdoors (cold); breathing in smoke, fumes (such as welding or exhaust fumes), powder, or dust (such as wood dust or mineral dust), etc. (dust and fumes); breathing in vapors such as solvents and thinners (vapors); handling or being in skin contact with chemical products or substances (chemicals); handling or being in direct contact with materials that could be infectious, such as waste, bodily fluids, laboratory materials, etc. (infectious agents); tiring or painful positions (static postures); standing, lifting, or moving people (lifting); carrying or moving a heavy manual handling (heavy loads); and repetitive hand or arm movements (repeated movement). Possible answers were on a 7-point scale equivalent to that assessing level of exposure to second-hand smoke. Participants who responded, 'approximately half the time' and above to each question (equivalent to 'high' exposure to second-hand smoke) were classified being exposed to each factor. The total number of co-exposed hazards was then calculated. Participants who were co-exposed to 1 or more co-exposure hazards were considered co-exposed to occupational hazards.

Covariates

Potential confounders and covariates included age (grouped as <30, 30–39, 40–49, and ≥50 years of age) and sex, socioeconomic status such as level of education: below elementary, middle school, high school, and further education or university graduate), and household income (grouped as quartiles). Health status and behavior included chronic diseases diagnosed by physicians (hypertension and obesity), alcohol drinking ('heavy' alcohol consumption indicated at least seven glasses of alcohol two or more times per week for males and >5 glasses for females), smoking (smokers and non-smokers), and self-rated health status (using the question 'How is your health in general?') and then grouping responses as 'healthy' (very good and good), 'moderate' (fair), and 'unhealthy' (bad and very bad).

Statistical analysis

Statistical analysis was performed using SAS statistical software (version 9.4; SAS Institute Inc., Cary, NC, USA). Chi-square tests were used to compare differences from baseline characteristics according to occupational injury (Table 1). The odds ratios (ORs) and 95% confidence intervals (95% CIs) for occupational injury were estimated using a logistic regression model that adjusted for age (continuous), sex, education, household income, occupational classification, long working hours, working schedule, self-satisfaction level (health and work), co-exposure to occupational hazards factors, smoking status, smoke-free policy in the workplace, alcohol drinking, and chronic disorders (hypertension and obesity). Further analysis was then performed to calculate the risk of occupational injury related to workplace smoking policy with stratification by sex, smoking status, smoke-free policy in the workplace, and each occupational characteristic (occupational classification, working schedule, long working hours, and co-exposure to occupational hazards). A binomial classification of exposure to environmental tobacco smoke ('none' and 'exposed') was used to analyze stratified occupational characteristics. The exposed group included those with moderate and high exposure to environmental tobacco smoke in the workplace. The reference group for each analysis was that not exposed to exposure to second-hand smoke. A two-tailed P value <0.05 was considered statistically significant.

Results

In our study, there were 998 (2.0%) cases of occupational injury, comprising 698 (2.5%) men and 300 (1.4%) women, from a total of 49 106 respondents (28 125 men and 20 981 women). Table 1 shows occupational injury cases (%) for the study population. The categories with the highest percentage of occupational injuries were: ≥50 years of age (2.5%), green-collar workers (4.1%), workers with low job satisfaction (5.8%), unhealthy workers (4.6%), and those co-exposed to occupational hazards (2.3%). There were 153 (7.1%) cases of occupational injury among workers with 'high' exposure to second-hand smoke. The highest percentage of occupational injuries occurred in smoking workplaces (2.7%).

Table 1. Baseline characteristics of study participants according occupational injury.

Characteristic	Percentage of occupational injury	No. of occupational injury cases	Total no. of participants	*P* values
All participants	2.0	998	49 106	
Socioeconomic status				<0.0001
Gender				
Men	2.5	698	28 125	
Women	1.4	300	20 981	
Age				<0.0001
<30	1.1	059	5202	
30–39	1.8	200	11 377	
40–49	2.0	283	14 122	
≥50	2.5	456	18 405	
Education level				<0.0001
Elementary school	2.9	134	4591	
Middle school	3.2	152	4825	
High school	2.4	466	19 866	
University	1.2	246	19 824	
Household income				0.0008
1st Quartile	2.0	319	16 126	
2nd Quartile	2.8	252	8938	
3rd Quartile	2.1	266	12 742	
4th Quartile	1.4	161	11 300	
Occupational characteristics				
Occupational classification[a]				<0.0001
White collar	0.9	105	11 251	
Pink collar	1.4	291	20 525	
Green collar	4.1	189	4597	
Blue collar	3.2	413	12 733	
Working schedule				0.5255
Shift	1.9	056	2989	
Fixed	2.0	942	46 117	
Long working hours (≥ 52 hours per week)				<0.0001
Yes	2.5	492	19 663	
No	1.7	506	29 443	
Self-rated job satisfaction				<0.0001
Satisfaction	1.7	047	2751	
Moderate	2.0	894	45 378	
Dissatisfaction	5.8	057	977	
Co-exposure to occupational hazardous factors[b]				<0.0001
No	1.6	277	17 822	
Yes	2.3	721	31 284	
Health status				
Self-rated health status				<0.0001
Healthy	1.3	439	32 759	
Moderate	3.2	446	13 887	
Unhealthy	4.6	113	2460	

Table 1. *Continued*

Characteristic	Percentage of occupational injury	No. of occupational injury cases	Total no. of participants	*P* values
Hypertension				<0.0001
Yes	3.0	112	3721	
No	1.9	886	45 385	
Obesity				<0.0001
Yes	5.3	051	962	
No	2.0	947	48 144	
Alcohol drinking				0.0013
None	2.0	268	13 189	
Light	1.7	403	23 404	
Heavy	2.6	327	12 513	
Smoking-related factors				
Smoking				<0.0001
Nonsmoker	1.7	459	27 221	
Smoker	2.5	539	21 885	
Second-hand smoke exposure status at workplace				<0.0001
None	1.2	382	32 281	
Moderate	3.2	463	14 660	
Severe	7.1	153	2165	
Smoke-free policy at workplace				<0.0001
Completely non-smoking workplace	1.2	239	19 688	
Non-smoking workplace with separated smoking area	2.3	148	6343	
Smoking workplace	2.7	611	23 075	

[a]Occupational classification: white-collar workers (managers, professionals, technicians, and associate professionals), pink-collar workers (clerical support, service, and sales workers), green-collar workers (skilled agricultural, forestry, and fishery workers), and blue-collar workers (crafts and related trades, plant and machine operators and assemblers, and elementary occupations).

[b]Occupational hazardous factors: vibration, noise, heat, cold, dust, fume, vapors, chemicals, infectious agents, static postures, standing, lift, and repeated movement.

Smokers accounted for a significantly higher percentage of those suffering occupational injuries than non-smokers (2.5% vs. 1.7%).

Table 2 shows the relationship between occupational injury and level of exposure to second-hand smoke using logistic regression. There was a dose–response relationship between exposure level of exposure to second-hand smoke and occupational injury after full adjustments were made. After stratification by sex, the increase in risk of occupational injury was similar for both men and women depending on their level of exposure to second-hand smoke. There was a significant, dose-dependent relationship between risk of occupational injury and level of exposure to second-hand smoke for both smokers and non-smokers (for smokers, moderate exposure—OR 1.87, 95% CI 1.54–2.27 and high exposure—OR 2.80, 95% CI 2.10–3.73; for non-smokers, moderate exposure—OR 2.85, 95% CI 2.33–3.49 and high exposure—OR 3.63, 95% CI 2.55–5.16). Moreover, there was a significant relationship between exposure to second-hand smoke in the workplace and occupational injury, depending on the smoke-free policy in the workplace. The strongest association between occupational injury and high level of exposure level to exposure to second-hand smoke was found in workers in completely non-smoking workplaces (moderate exposure—OR 3.75, 95% CI 2.85–4.93; high exposure—OR 4.23, 95% CI 2.35–4.78). In non-smoking workplaces with a separate smoking area, the odds of occupational injury were 2.98 (95% CI 1.57–5.67) in the high exposure group. In smoking workplaces without any designated smoking areas, there was also a significant association between exposure to second-hand smoke and occu-

Table 2. Results of odds ratio (95% CI) for assessment of the relationship between second-hand smoke exposure level and occupational injury using logistic regressions.

Second-hand smoke exposure level	Occupational Injury		
	OR	95% CI	*P* for trend
All participants (*n* = 49 106)			<0.0001
None	1.00	Reference	
Moderate	2.28	1.98–2.62	
Severe	3.19	2.56–3.98	
Gender			
Men (*n* = 28 125)			<0.0001
None	1.00	Reference	
Moderate	2.12	1.84–2.60	
Severe	3.44	2.67–4.45	
Women (*n* = 20 981)			<0.0001
None	1.00	Reference	
Moderate	2.53	1.99–3.22	
Severe	2.32	1.44–3.74	
Smoking status			
Smokers (*n* = 21 885)			<0.0001
None	1.00	Reference	
Moderate	1.87	1.54–2.27	
Severe	2.80	2.10–3.73	
Non-smokers (*n* = 27 221)			<0.0001
None	1.00	Reference	
Moderate	2.85	2.33–3.49	
Severe	3.63	2.55–5.16	
Smoke-free policy at workplace			
Completely non-smoking workplace (*n* = 19 688)			<0.0001
None	1.00	Reference	
Moderate	3.75	2.85–4.93	
Severe	4.23	2.35–4.78	
Non-smoking workplace with separated smoking area (*n* = 6343)			<0.0001
None	1.00	Reference	
Moderate	3.13	2.16–4.55	
Severe	2.98	1.57–5.67	
Smoking workplace (*n* = 23 075)			<0.0001
None	1.00	Reference	
Moderate	1.68	1.40–2.02	
Severe	2.84	2.19–3.69	

All models were adjusted for age (continuous), sex, education, income, occupational characteristics (occupational classification, work schedule, work time, self-satisfaction level, and co-exposure to occupational hazardous factors), and health status (self-rated health status, hypertension, obesity, and alcohol drinking).

pational injury depending on the level of exposure to exposure to second-hand smoke (moderate exposure—OR 1.68, 95% CI 1.40–2.02; high exposure—OR: 2.84, 95% CI 2.19–3.69). For all strata, there was a dose–response relationship between level of exposure to second-hand smoke and occupational injury (*P* value for trend <.0001).

Fig. 1 shows the results from multivariable logistic regression analysis of the relationship between occupational injury and exposure to second-hand smoke according to occupational characteristics. Apart from green-collar workers, in all strata the risk of occupational injury increased significantly with exposure to second-hand smoke in the workplace. When results were stratified by occupational classification, white-collar workers group had the highest OR (95% CI) for occupational injury compared with the group not exposed to exposure to second-hand smoke.

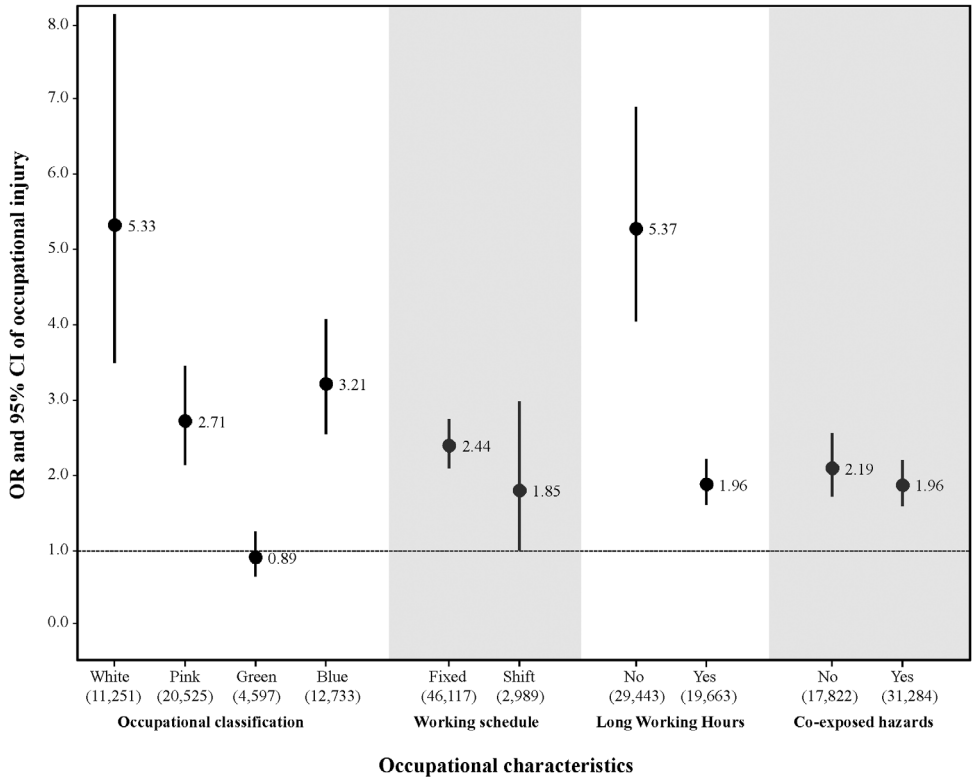

Figure 1. Odds ratios (OR) and 95% confidence intervals (CI) of relationship between exposure to second-hand smoke and occupational injury stratified by occupational classification, working schedule, long working hours, and co-exposure to hazards in the workplace. All models were adjusted for age (continuous), sex, education, household income, occupational characteristics (occupational classification, work schedule, working hours, level of satisfaction, and co-Exposure to occupational hazardous factors), health status (self-rated health status, hypertension, obesity, and alcohol consumption), and smoking-related factors; stratification covariates are excluded. The reference group for each stratum was the group not exposed group to second-hand smoke.

Discussion

This study set out with the aim of assessing the association between exposure to second-hand smoke in the workplace and occupational injury. The results of this study indicate that occupational injury is significantly associated with level of exposure to second-hand smoke in a dose–response manner. Specifically, groups of participants with moderate and high levels of exposure to second-hand smoke had significantly higher risk of occupational injury than the group not exposure to second-hand smoke, after stratification according to sex, smoking status, and smoke-free policy in the workplace. This relationship did not attenuate even after controlling for various potential covariates.

There is little published data on the association between exposure to second-hand smoke and occupational injury. Only a few studies in the field of occupational accidents or injury have focused on passive smoking. A strong relationship between workplace exposure to tobacco smoke and occupational injury has been reported in a previous study (Chau *et al.*, 2008). Workers exposed to smoking can be affected by physical and psychomotor dysfunction, and these are associated with exacerbation of existing occupational injuries (Woolf *et al.*, 1999; Fulda and Schulz 2001; Kalmijn *et al.*, 2002). A longitudinal epidemiological study demonstrated that sleep problems, including obstructive sleep apnea syndrome, were associated with an increased risk of occupational injury (Lindberg *et al.*, 2001). Exposure to smoke is a known risk factor for sleep apnea and sleep disturbance (Hoflstein, 2002). Smoking, and possibly exposure to second-hand smoke, might aggravate sleep disorders, and physical and psychological dysfunction are linked to increased risk of occupational injury. This hypothesis is further supported by studies that have reported that exposure to second-hand smoke is associated with sleep disorders, and decreased physical and mental functioning (Punjabi, 2008; Llewellyn *et al.*, 2009).

Exposure to second-hand smoke was related to symptoms of ocular irritation and respiratory tract disruption. In several previous studies, these symptoms have been explained as being due to impairment of mucociliary function in the respiratory tract and direct irritation of the ocular surfaces (Köseoğlu *et al.*, 2006; Forastiére *et al.*, 1992; Sahai and Malik, 2005; Altinors *et al.*, 2006). According to some studies, discomfort, eye symptoms, and nose irritation increase in a direct relationship to the increase in concentration of environmental tobacco smoke (Muramatsu *et al.*, 1983; Weber, 1984). Exposure to second-hand smoke also can induce fatigue by elevating blood carboxyhemoglobin levels (McDonough and Moffatt, 1999) and disturbing sleep (Franklin *et al.*, 2004; Nakata *et al.*, 2008). These symptoms are far more profound than personal inconvenience because of their negative effects in working environments. Discomfort and fatigue deplete the capacity of workers to deal with stress, negatively affect workers' ability to perform job tasks, and decrease productivity (Reynolds *et al.*, 2004; Ricci *et al.*, 2007). They also play a major role in occupational injuries and accidents (Melamed *et al.*, 1989; Wegman and Fine, 1990). Workers suffering from these unpleasant conditions are less vigilant and less likely to communicate promptly in risky situations (Swaen *et al.*, 2003; Swaen *et al.*, 2004). Therefore, workers who are in discomfort or fatigued are more easily exposed to those dangerous situations which cause injuries or accidents than workers without these symptoms (Clarke and Robertson, 2005; Chi *et al.*, 2005).

Smoking exposure in the workplace could be an indication of poor working and safety conditions. According to a previous study, workplaces which allowed smoking had significantly poorer working conditions and safety environments (Zellers *et al.*, 2007). Poor working conditions related to smoking exposure could play an important role in injury or accidents in the workplace (Ghosh *et al.*, 2004; García-Herrero *et al.*, 2012). The significantly increased risk of occupational injury found in the current study among workers exposed to second-hand smoke exposure in the workplace may be explained by aggravated poor working and safety conditions in the workplace due to exposure to tobacco smoke.

Another important finding of our study was the difference in risk of occupational injury according to the smoking policy of the workplace and smoking status of individuals. To reduce the hazardous effects of exposure to second-hand smoke, many countries have implemented comprehensive smoke-free legislation indoors; such regulation is, however, limited in in Korea. In 2011, the Korean government amended Article 9 of the National Health Promotion Act (NHPA) to implement a smoke-free policy in indoor public spaces including public institutions and hospitality venues. However, there was no legislation to make workplaces (e.g., offices or factories) with an indoor net area of <1000 m^2 smoke-free. Even in indoor public places or smoke-free workplaces, the NHPA provided for installation of separate indoor or outdoor smoking areas. Contrary to expectation, in our study, workers in completely smoke-free work areas had increased risk of occupational injury compared with workers in workplaces with separate smoking rooms or without a smoke-free policy at work. Moreover, non-smokers were more vulnerable to occupational injury associated with exposure to second-hand smoke than smokers. Although exposure to second-hand smoke generally has been linked to occupational injury, there is much less information about the effect of exposure to second-hand smoke in the workplace. According to a previous study, industries with no restrictions on smoking in the workplace had higher costs due to occupational injury than those with smoke-free policies (Tsai *et al.*, 2005). Another prospective cohort study and review also reported increased injury and accidents in the workplace among smokers compared with non-smokers (Ryan *et al.*, 1992; Sacks and Nelson, 1994). However, the current study showed that the risk of occupational injury associated with the level of exposure to second-hand smoke was higher in completely smoke-free workplaces than those with separate smoking areas or those with no restrictions of smoking in the workplace; it was also higher among non-smokers than smokers. Thus, workers in completely smoke-free workplaces and non-smokers may be more vulnerable to occupational injury associated with exposure to second-hand smoke. Workers in completely smoke-free workplaces and non-smokers might suffer irritation and discomfort more readily from exposure to smoking. Therefore, a policy of smoke-free workplaces is not sufficient to protect workers, particularly non-smokers, from ill health due to exposure to second-hand smoke even in workplaces where smoking is completely restricted, although such a policy is a starting point.

The increased risk of occupational injury associated with exposure to second-hand smoke according to workplace smoking policy and smoking status parallels the difference in risk of occupational injury according to occupational characteristics among those exposed to environmental tobacco smoke. Manual workers (pink- or blue-collar workers in this study), shift workers and those working long hours, and those exposed to various occupational hazards were vulnerable to occupational injury (Harrell, 1990; Vegso *et al.*, 2007; Lim *et al.*, 2012).

However, in the current study, the risk of occupational injury among workers exposed to environmental tobacco smoke was higher than that among white-collar workers, those with a regular work schedule, those working standard hours, and those not co-exposed to occupational hazards who were also not exposed to environmental tobacco smoke. Exposure to second-hand smoke in the workplace might be closely linked to occupational injury even among workers in standard- or high-safety working environments. A probable explanation for this might be that exposure to second-hand smoke in the workplace has extensive effects on safety in the workplace due to the general toxicology of tobacco smoke. Workers may be more highly susceptible to exposure to second-hand smoke in safer or cleaner working environments. Therefore, it is necessary to adopt proactive approaches to protect vulnerable workers to occupational injury linked to exposure to second-hand smoke even in clean and safe workplaces.

These findings enhance our understanding of the effect of exposure to second-hand smoke on occupational environments, particularly in relation to injury. However, these results may be somewhat limited by the nature of the data from the KWCS. The KWCS has a cross-sectional design. Thus, we could not conclude that there was a causal relationship between exposure to second-hand smoke in the workplace and occupational injury. When considering the mechanisms of occupational injury, the increased risk of occupational injury could be explained by exposure to environmental tobacco smoke from other workers, but this does not explain the reverse relationship. A longitudinal study would be needed to reveal a specific cause-and-effect relationship between occupational injury and exposure to second-hand smoke in order to protect workers' health. Another limitation is that we measured occupational injury and exposure to second-hand smoke of workers using self-reported questionnaires. Although these are considered reliable and valid (Avila-Tang *et al.*, 2013; Lee *et al.*, 2014), workers may be affected by recall bias and misreport variations in exposure to environmental tobacco smoke. When analyzing self-reported data, researchers should be aware that self-reported occupational injuries have known to be affected by information or recall bias (Swaen *et al.*, 2004; Alzahrani *et al.*, 2016). However, in a study which examined the correlation between self-reported data and actual incidence of occupational injuries, researchers computed the incidence rates from self-reported data and compared them with officially investigated data to evaluate the reliability; they concluded that self-reported data relating to being injured in the workplace rationally reflected the actual incidence of work-related injuries (Asfaw *et al.*, 2012). In the same vein, we inferred that the self-reported data used in this study were reliable in reflecting the real incidence of occupational injuries in Korea. Lastly, various confounders that may have a link to occupational injury or exposure status to second-hand smoke, such as age, sex, socioeconomic status, health status, occupational characteristics, and workplace environment, were adjusted or stratified in this study. However, it is unclear whether there may have been other potential confounding factors related to occupational injury or exposure status to second-hand smoke that were difficult to control for or assess, such as unreported workplace conditions and other routes of exposure routes to exposure to second-hand smoke. For example, to understand the effects of exposure to second-hand smoke, it is important to consider various routes of exposure, such as those in home, public places, or other environments. The KWCS includes exposure to second-hand smoke in the workplace but does not include other exposure routes. We were, therefore, unable to conduct detailed controlled or stratified analysis of various routes of exposure to second-hand smoke due to the nature of the data. Thus, the results from current study on the effects of exposure to second-hand smoke cannot be extrapolated to workers generally, although, among non-smoking workers, it has been found that most exposure to exposure to second-hand smoke happens in the workplace (Wortley *et al.*, 2002).

Conclusions

The present study has shown that the association between exposure to second-hand smoke and occupational injury has a dose–response relationship. Furthermore, we have demonstrated that workers in safe or clean workplaces might be preferentially vulnerable to occupational injury. The findings of the present study provide insight into research and policy on restricting exposure to smoking among the working population.

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