RESEARCH ARTICLE

Policy Effects of Secondhand Smoke Exposure in Public Places in the Republic of Korea: Evidence from $PM_{2.5}$ levels and Air Nicotine Concentrations

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Abstract

Objective: The purpose of this study was to evaluate secondhand smoke (SHS) exposure inside selected public places to provide basic data for the development and promotion of smoke-free policies. Methods: Between March and May 2009, an SHS exposure survey was conducted. $PM_{2.5}$ levels and air nicotine concentrations were measured in hospitals (n=5), government buildings (4), restaurants (10) and entertainment venues (10) in Seoul, Republic of Korea, using a common protocol. Field researchers completed an observational questionnaire to document evidence of active smoking (the smell of cigarette smoke, presence of cigarette butts and witnessing people smoking) and administered a questionnaire regarding building characteristics and smoking policy. Results: Indoor $PM_{2.5}$ levels and air nicotine concentrations were relatively higher in monitoring sites where smoking is not prohibited by law. Entertainment venues had the highest values of $PM_{2.5}$($\mu g/m^3$) and air nicotine concentration($\mu g/m^3$), which were 7.6 and 67.9 fold higher than those of hospitals, respectively, where the values were the lowest. When evidence of active smoking was present, the mean $PM_{2.5}$ level was 104.9 $\mu g/m^3$, i.e., more than 4-fold the level determined by the World Health Organization for 24-hr exposure (25 $\mu g/m^3$). Mean indoor air nicotine concentration at monitoring sites with evidence of active smoking was 59-fold higher than at sites without this evidence (2.94 $\mu g/m^3$ vs. 0.05 $\mu g/m^3$). The results were similar at all specific monitoring sites except restaurants, where mean indoor $PM_{2.5}$ levels did not differ at sites with and without active smoking evidence and indoor air nicotine concentrations were higher in sites without evidence of smoking. Conclusion: Nicotine was detected in most of our monitoring sites, including those where smoking is prohibited by law, such as hospitals, demonstrating that enforcement and compliance with current smoke-free policies in Korea is not adequate to protect against SHS exposure.

Keywords: Secondhand smoke - air nicotine - $PM_{2.5}$ - smoke free policy

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Introduction

Secondhand smoke (SHS) is a mixture of smoke emitted from the burning end of tobacco products and the smoke exhaled from the lungs of smokers, and contains at least 250 chemicals that are known to be carcinogenic or toxic to humans (National Toxicology Program, 2011). As of 2004, 40% of the world's children, 33% of non-smoking men, and 35% of non-smoking women were exposed to SHS (Oberg, 2011). This exposure is estimated to cause 0.7% of the worldwide burden of disease, accounting for over 10 million disability-adjusted life years (Oberg et al., 2011).

The International Agency for Research on Cancer and the United States Surgeon General have concluded that SHS exposure causes respiratory and cardiovascular diseases, cancer and premature death among non-smoking adults, and increases the risk for sudden infant death syndrome, acute respiratory infections, middle-ear disease, and exacerbation of asthma in children(National Toxicology Program, 2011; IARC, 2002). Article 8 of the World Health Organization Framework Convention on Tobacco Control calls for the adoption of smoke-free legislation for universal protection against SHS exposure. As a result, more and more governments worldwide who have signed and ratified this Convention are implementing smoke-free policies that prohibit smoking in all indoor public places and workplaces, including restaurants and bars. However, a 2011 report from the World Health Organization stated that only 11% of the global population

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is protected by smoke-free policies that prohibit smoking in bars, restaurants and nightclubs(WHO, 2011).

The Republic of Korea has one of the highest smoking prevalences in Asia, in particular among adult males (prevalence was 70% from 1980 to the early 1990s). In 2001, when the smoking rate of adult male and female were 60.9% and 5.2%, respectively, the government started anti-smoking programs with the aim of reducing smoking prevalence among males and females to 30% and 5%, respectively by 2010. As a result, smoking rates in adult males reduced about 4-5% annually through 2009. As of 2010, the smoking rate was 48.3% among adult males and 6.3% in adult females(Center for Disease Control and Prevention, 2011). Despite this reduction, smoking prevalence is still quite high among adult males as compared to other OECD countries. One of the aims of Korea's Health Plan 2020 is to decrease smoking prevalence among adult males to 29% by the year 2020.

Since the enactment of the National Health Promotion Act in Korea in 1995, smoke-free policies have led to the designation of non-smoking areas in several settings, such as large buildings, theaters, stores, hospitals, schools, concert halls, gyms, and public transportation. After 1995, the number of smoke-free settings was gradually expanded to include public baths in 1999; youth arcades, game rooms, large restaurants, comic book stores, government buildings, and nursery schools in 2003; and factories, local government buildings, and indoor work places in 2006. In 2010 and 2012, the National Health Promotion Act was again revised, expanding the designation of non-smoking areas to include restaurants and game rooms, as well as some outdoor areas such as public parks, streets, bus stations, and other public places(Levy et al., 2010; Ministry of Health and Welfare, 2010). However, the smoke-free policies in Korea still don't apply to entertainment venues such as bars and pubs, where smoke-free policies are urgently needed.

Despite this progress, valid data on the extent of SHS exposure was lacking. In this context, the purpose of this study was to evaluate SHS exposure in selected public places in Seoul, Korea, in order to provide basic data for the further development and promotion of smoke-free policies.

Materials and Methods

Data collection

This cross-sectional SHS exposure survey measured $PM_{2.5}$ levels and air nicotine concentrations in 29 selected public places: government buildings (n=4), hospitals (n=5), restaurants (n=10) and entertainment venues (n=10) in Seoul, Korea. Measurements were taken between March and May 2009. There were 75 SHS monitoring locations across the 29 monitoring sites. In government buildings, the locations were offices, the lobby, the cafeteria and the restrooms (male/female); in hospitals, monitoring locations included the lobby/waiting room, doctors' lounge, patient floor, restrooms (male/female) and stairwells; in restaurants they were in the main dining area; and, in entertainment venues they were in the main audience area. In government buildings and hospitals, smoking is prohibited by law, whereas smoking is not prohibited by law in restaurants and entertainment venues.

Field researchers completed an observational questionnaire to document evidence of active smoking (i.e., the smell of cigarette smoke, presence of cigarette butts and witnessing people smoking) The questions included, among others, the "Number of smokers", "Any cigarette butts on the floor?", and "Any smell of cigarette smoke?" The field researchers also administered a building questionnaire to either the building manager or other appropriate personnel regarding building characteristics and smoking policy. For example:

- "Does this building [hospital, government building, restaurant, bar/nightclub] have a ventilation system for extracting smoke?"
- "What type of air conditioning system does this building have?"
- "What is the source of heat for this building?"
- "Which of the following best describes where smoking is allowed in indoor areas of this building"
- "Does this establishment have a rule that restricts smoking in any way?"
- "Are there 'No Smoking' signs posted inside the building?"

The overall monitoring plan and protocol was designed based on the suggestions of the Institute for Global Tobacco Control at the Johns Hopkins Bloomberg School of Public Health. Each monitoring site was selected after considering its public and political impact in Korea. In government buildings, some areas such as cafeterias, smoking zones, and the perimeter of building were included as SHS monitoring locations. For hospitals, government hospitals and private hospitals with over 1,000 beds were selected. For restaurants and entertainment venues, both those with and without designated no smoking sections as per current law were selected.

$PM_{2.5}$ monitoring

The TSI SidePak AM510 Personal Aerosol Monitor was used in this study. It is a battery operated aerosol monitor (TSI Incorporated, Shoreview, Minnesota, USA) fitted with an impactor to measure $PM_{2.5}$ levels. The monitor was placed in a small bag with a short length of Tygon tubing attached to the monitor inlet and the other end protruding outside the bag. The monitor was calibrated each day before use and the airflow rate set at 1.7 l/min. The monitor draws in air continuously and reads $PM_{2.5}$ levels at 60-second intervals.

The field researcher switched on the SidePak at least 10 minutes before entering a monitoring site to measure external levels of $PM_{2.5}$. After entering the monitoring site, the SidePak was either positioned in a single location, or circulated throughout the room. Care was taken to avoid damaging the device and to monitor the air within people's normal breathing zone. $PM_{2.5}$ monitoring was carried out in this manner for a minimum of 30 minutes at each site. Details regarding the layout of the monitoring site and other relevant data, such as the use of ventilation systems, were noted according to the monitoring protocol.

Table 1. Distribution of Indoor and Outdoor $PM_{2.5}$ Levels($\mu g/m^3$) and Indoor Air Nicotine Concentrations($\mu g/m^3$) in Different Monitoring Sites

Monitoring site		N	Mean	SD	GM	GSD	Min	25th	Median	75th	Max
$PM_{2.5}$ level											
Government	Outdoor	4	25.2	13.9	20.5	2.0	7.5	15.3	26.2	35.0	40.7
	Indoor	4	20.4	10.0	17.8	1.9	7.0	13.4	21.9	27.4	30.8
Hospital	Outdoor	5	25.2	9.72	21.8	1.70	8.85	24.5	28.1	30.4	33.8
	Indoor	5	19.0	7.39	17.0	1.70	7.26	16.4	22.7	23.1	25.6
Entertainment	Outdoor	10	60.0	51.6	32.5	1.84	18.8	25.5	40.4	62.0	165.5
	Indoor	10	144.9	78.1	102.5	2.01	18.4	104.2	128.9	213.7	292.3
Restaurant	Outdoor	10	19.5	14.5	14.9	1.77	9.41	10.2	12.6	24.6	49.8
	Indoor	10	44.2	51.6	27.7	2.41	11.0	18.9	22.9	58.0	180.2
Air nicotine concentration											
Government		31	0.54	0.45	0.03	3.32	<LOD	0.22	0.55	0.80	1.88
Hospital		43	0.07	0.19	0.03	3.78	<LOD	0.01	0.03	0.05	0.97
Entertainment		18	4.75	5.35	1.55	12.4	<LOD	1.79	2.65	6.02	19.9
Restaurant		19	0.21	0.99	0.26	6.42	<LOD	0.01	0.02	0.04	6.46

SD, Standard Deviation; GM, Geometric Mean; GSD, Geometric Standard Deviation.

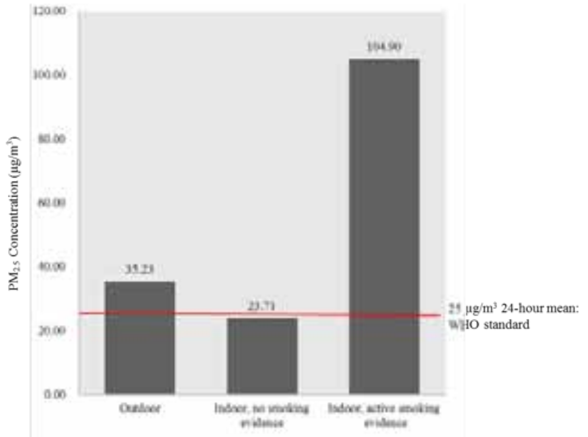

Figure 1. Mean Indoor and Outdoor of $PM_{2.5}$ Levels by Presence of Active Smoking Evidence

The number of patrons and the number of those actively smoking were recorded at three time points (upon entry, after 15 minutes and at exit). After exiting the monitoring site, field researchers spent another 10 minutes outside the site before stopping $PM_{2.5}$ monitoring. The field researchers were trained to use $PM_{2.5}$ and air nicotine monitors regarding the standardized protocol from the Johns Hopkins Bloomberg School of Public Health.

Air nicotine monitoring

Air nicotine levels in each monitoring location weree estimated by passive sampling of vapor-phase nicotine using a filter badge treated with sodium bisulphate developed by Hammond et al(1987). No outdoor air nicotine measurements were taken. Passive air monitors were installed in each monitoring location for 7 days. The monitors were placed as close as possible to the middle of the monitoring locations, consistent with the following guidelines:

- Hang the monitor in the air1-2 meters from the floor.
- Hang monitors at least 1 meter away from an open window or a ventilation system.
- Hang monitors at least 1 meter away from a potential regular smoker.
- Do not hang monitors in an area where air does not circulate (i.e., "dead spots"), such as a corner, under a shelf, or on curtains.
- Ensure monitors are not too visible or accessible to avoid people tampering with them(Some good places include beams, nails or even plants or lamps).

The nicotine collected by each passive sampler was extracted into heptanes with an internal standard (Isoquinoline)and then injected into a gas chromatograph,coupled with a nitrogen phosphorus detector. For quality control purposes, 10% of samples were duplicates and blanks.Using the analytic results from blank samples, the median limit of detection was determined to be $0.0048 \mu g/m^3$ for a 7-day sample. Final concentrations were provided after subtraction of background levels from the blank samples.

Data analysis

Data analysis for the air nicotine monitors was completed using gas chromatography by the Department of Environmental Sciences at the Johns Hopkins Bloomberg School of Public Health.

Descriptive statistics including the geometric and arithmetic means, standard deviation, minimum, maximum and median were generated for $PM_{2.5}$ levels and air nicotine concentrations across the whole dataset and then subdivided by monitoring site and active smoking evidence. Statistical analyses were carried out using SAS V.9.2.

Results

Indoor $PM_{2.5}$ levels and air nicotine concentrations were relatively higher in monitoring sites where smoking is not prohibited by law. Entertainment venues had the highest values of $PM_{2.5}$($\mu g/m^3$) and air nicotine concentration($\mu g/m^3$), which were 7.6 and 67.9 fold higher than those of hospitals, respectively, where the values were the lowest. However, when comparing indoor and outdoor $PM_{2.5}$ levels, outdoor levels were higher than indoor levels in sites where smoking is prohibited by law (e.g., government buildings and hospitals), while outdoor $PM_{2.5}$ levels were lower than indoor levels in restaurants and entertainment venues where smoking is not prohibited

Table 2. Indoor $PM_{2.5}$ level(μg/m³) and Indoor Air Nicotine Concentration(μg/m³) in Monitoring Sites by Presence of Active Smoking Evidence

Monitoring site	PM2.5 level						Air nicotine concentration					
	Active smoking	N	Mean	SD	GM	GSD	Active smoking	N	Mean	SD	GM	GSD
Government	No	4	20.4	10.0	17.8	1.92	No	29	0.03	0.02	0.02	2.34
	Yes	-	-	-	-	-	Yes	2	0.73	0.35	0.68	1.65
Hospital	No	5	19.0	7.39	17.0	1.70	No	40	0.04	0.10	0.02	2.44
	Yes	-	-	-	-	-	Yes	3	2.44	3.49	0.93	5.99
Entertainment	No	1	18.5	-	18.4	-	No	2	0.00	0.00	0.00	1.00
	Yes	9	158.9	68.1	123.9	71.5	Yes	16	5.34	5.39	3.49	2.59
Restaurant	No	2	44.7	36.4	34.8	2.69	No	6	0.70	0.19	0.68	1.34
	Yes	8	44.1	56.9	26.3	2.48	Yes	13	0.46	0.51	0.16	8.25

SD, Standard Deviation; GM, Gometric Mean, GSD, Geometric Standard Deviation

Table 3. Indoor Air Nicotine Concentration (μg/m³) in Monitoring Sites by Monitoring Location

Monitoring location	N	Mean	SD	GM	GSD
Government					
Offices	10	0.03	0.02	0.02	2.03
Lobby	3	0.03	0.04	0.02	4.10
Cafeteria	10	0.17	0.32	0.05	5.59
Restrooms	8	0.02	0.01	0.02	1.99
Hospital					
Waiting room	5	0.02	0.00	0.02	1.15
Doctors' lounge	5	0.14	0.27	0.04	6.23
Patient floor	10	0.03	0.04	0.02	2.69
Cafeteria	9	0.02	0.01	0.02	1.55
Restrooms	9	0.81	2.13	0.07	7.85
Stairwell	4	0.09	0.08	0.07	2.48
Entertainment					
Smoking section	16	5.34	5.39	3.49	2.59
Non-smoking section	2	0.00	0.00	0.00	1.00
Restaurant					
Smoking section	15	0.46	0.48	0.19	7.32
Non-smoking section	4	0.80	0.13	0.80	1.20

SD, Standard Deviation; GM, Geometric Mean; GSD, Geometric Standard Deviation

by law. In addition, government buildings showed the second highest indoor air nicotine concentration after entertainment venues (Table 1).

When evidence of active smoking was present, the mean indoor $PM_{2.5}$ level was 104.9 μg/m³, which was much higher than indoor $PM_{2.5}$ levels in the absence of active smoking evidence or all outdoor $PM_{2.5}$ levels combined. This $PM_{2.5}$ level was more than 4-fold the guideline level of 25 μg/m³ for 24-hr exposure set by the World Health Organization(2006)(Figure 1). Most active smoking evidence was seen in monitoring sites where smoking is not prohibited by law. The mean indoor air nicotine concentration in monitoring sites with active smoking evidence was 2.94 μg/m³, 59-fold higher than that in indoor monitoring sites without active smoking evidence (0.05 μg/m³) (data not Shown). Higher mean indoor $PM_{2.5}$ levels and indoor air nicotine concentrations were observed in all monitoring sites with evidence of active smoking except for restaurants, where the mean $PM_{2.5}$ level was not different in sites with and without active smoking evidence and where indoor air nicotine concentrations were higher in sites without active smoking evidence (Table 2).

Indoor air nicotine concentrations also differed by monitoring location. Air nicotine concentrations in monitoring locations such as cafeterias in government buildings, and toilets or doctors' lounges in hospitals, were higher than those in other monitoring locations, even if the overall indoor air nicotine concentration was relatively low when compared with monitoring sites such as entertainment venues and restaurants where smoking is not prohibited by law. In entertainment venues, air nicotine levels in smoking sections were higher than in non-smoking sections, while, in restaurants, air nicotine concentrations in non-smoking sections were much higher than in smoking sections (Table 3). In entertainment venues, the evidence of active smoking was identified in all smoking section, while any evidence of active smoking was not identified in all non-smoking sections. In restaurants, the evidence of active smoking was identified in most of smoking sections (Geometric Means (GM): 0.16 μg/m³, Geometric Standard Deviation (GSD): ± 8.25) except for 2 places (GM: 0.49 μg/m³, GSD: ±1.17), while any evidence of active smoking was not identified in all non-smoking sections where air nicotine concentration was higher than those in smoking sections with or without evidence of active smoking (data not shown).

Discussion

As Korea has a high smoking prevalence, a high level of SHS exposure is to be expected. However, there was no data to measure the level of SHS exposure to provide localized evidence to impact smoke-free policies and their real implementation in the community In these aspects, the present study showed novel findings on SHS exposure, allowing for a comparison of $PM_{2.5}$ levels and air nicotine concentrations in monitoring sites where smoking is and is not prohibited by law, and by evidence of active smoking that reflected actual smoking practices at the site. As expected, a relatively high level of SHS exposure was observed in monitoring sites where smoking is still allowed under the law and where evidence of active smoking was seen. This was also the case in monitoring locations where smoking is prohibited by law, but compliance or enforcement are weak.

SHS exposure is an established cause of respiratory and cardiovascular diseases, cancer and premature death among non-smoking adults, and no level of SHS exposure is safe (Centers for Disease Control and Prevention, 2006). For this reason, public health policy in many countries has aimed to reduce SHS exposure for non-smokers on the basis of studies of $PM_{2.5}$ levels and air nicotine concentrations in public places. In recent years, surveys of SHS exposure have also been carried out in developing countries. In the present study, overall indoor air nicotine concentrations in public places in Korea were not low compared with other countries, although they were lower than those reported in China (i.e., median nicotine level: 0.17 $\mu g/m^3$ in hospitals, 0.48 $\mu g/m^3$ in government buildings, 2.17 $\mu g/m^3$ in restaurants, and 7.48 $\mu g/m^3$ in entertainment venues) (Stillman et al., 2007). Median air nicotine concentrations in Europe and in Latin America range from 0.01 to 4.0 $\mu g/m^3$ and from just over the limit of detection to 1.33 $\mu g/m^3$ in hospitals; 0.01 to 18 $\mu g/m^3$ and 0.15 to 2.52 $\mu g/m^3$ in restaurants; and 5 to 122 $\mu g/m^3$ and 1.26 to 6.21 $\mu g/m^3$ in entertainment venues (Barnoya, et al., 2007; Navas-Acien et al., 2004). In Korea, the median nicotine concentration in monitoring sites where smoking was prohibited by law, such as government buildings and hospitals, was similar to or higher than that in most Latin American countries, whereas the median air nicotine concentration in places where smoking is not prohibited by law, such as restaurants and entertainment venues, was lower than that in most Latin American countries. However, the patterns of nicotine distribution were similar to those of China, Europe, and Latin America (i.e., the concentrations were similarly high in entertainment venues).

This study shows that nicotine was detected in most monitoring sites, including those where smoking is prohibited by law, such as hospitals. $PM_{2.5}$ levels and air nicotine concentrations in entertainment venues and restaurants were higher than in other monitoring sites. Exposure levels at restaurants was high regardless of active smoking evidence or presence of a designated smoking section, which means that non-smoking sections in these restaurants did not effectively protect non-smokers from SHS exposure. Furthermore, regarding the higher air nicotine concentration in non-smoking sections than those in smoking section of restaurants, other factors such as their own smoke free policies or ventilation would affect the level of exposure. Smoking is prohibited by law in government buildings and hospitals in Korea, and although the observed overall nicotine level was low, levels were relatively high in the more private areas of hospitals, such as the restrooms. Nicotine levels in the cafeterias of government buildings were also high compared to other monitoring locations, possibly because smoking was previously permitted in the cafeteria of government buildings and, therefore, it may still be considered a smoke-friendly environment. These results show that smoke-free policies in Korea are not being rigorously enforced and do not fully protect against SHS exposure.

In agreement with the present study, the Korea National Health and Nutrition Survey 2010 also suggests that smoke-free policies in Korea are not effective. The prevalence of SHS exposure among non-smokers is a gradually growing trend; as of 2010, 39.7% (48.9% of men and 35.1% of women) of the Korean adult population was exposed to SHS at home or at work, in spite of reduced smoking prevalence (Center for Disease Control and Prevention, 2011). This is was less than the 49.2% reported in China (Gu, 2004), but more than the 14.3% exposure for male non-smokers and 13% for female non-smokers reported in Finland (Jousilahti and Helakorpi, 2002), and the 20.2% reported in the USA for never-smokers (Mannino, 1997). Furthermore, SHS exposure at work places in Korea is quite high (58.6% for non-smoking men and 41.8% for non-smoking women)(Center for Disease Control and Prevention, 2011), although it is lower than in Bangladesh (60.8%), Egypt (59.2%) and Vietnam (62.8%) (King et al., 2012).

As mentioned previously, mass media campaigns have been in place since smoking was prohibited in some public places in 1995 in accordance with the National Health Promotion Act of Korea. The goal of these campaigns is to educate and inform people of the harmful effects of smoking, including SHS, and to minimize SHS exposure. However, the present study suggests that a permissive environment for smoking has remained in most public places. As reported in a previous study on SHS exposure among non-smoking adults in Seoul, Korea (Hughes et al., 2008 a; Hughes et al., 2008 b), this situation may be the result of environmental and cultural factors related to smoking in Korea. Due to a long-standing high smoking prevalence rate among Korean males of more than 70%, most Korean people have accepted smoking in public places and tolerated exposure to SHS without complaint. Even females, who constitute the largest number of non-smokers, regard SHS exposure as normal and former smokers are accustomed to being in a smoking environment. In addition, in Korean culture, smoking and drinking are considered as a means of facilitating good social relationships. The results of this study and of previous reports support the suggestion of an association between smoking (and related SHS exposure) and alcohol drinking in the general population (Lee and Ha, 2011). This socio-cultural phenomenon might result in a lack of recognition of the harmful nature of SHS exposure among non-smokers, or among politicians and government officials who are responsible for developing and implementing smoking-related policies, resulting in weak tobacco control measures and poor enforcement and compliance.

The results of this study have a few limitations. The number of monitoring sites in the present study was relatively small, and did not cover all public places, which makes it difficult to argue that the study is representative of the state of SHS exposure throughout Korea. However, the objective of the study was to collect policy-relevant monitoring data that could be used to document SHS exposure in key areas and to promote smoke-free policies. We conducted a survey of SHS exposure in Seoul, the capital and the largest city in Korea, as a representative indicator city that should have a big influence on decision-making with regards to smoke-free policy. Finally, this survey of SHS exposure had a cross-sectional design and was therefore conducted at one point in time. Consequently, the results might underestimate or overestimate SHS exposure. However, as previously described, the protocol was based on the suggestions of the Johns Hopkins Bloomberg School of Public Health's Institute for Global Tobacco Control. The same protocol has been used in other Asian cities to allow for comparability across countries, and many studies of SHS exposure have used a cross-sectional design to inform the status of SHS exposure in countries or cities.

Since April 2010, when an amendment to Korea's National Health Promotion Act gave more authority to local governments to expand outdoor smoke-free areas, 85 local district offices have banned smoking on the street and in various other public areas. In addition, as of 2013 "absolute non-smoking areas" in the National Health Promotion Act were expanded to include restaurants larger than 150m^2. This will apply to restaurants larger than 100m^2 from January 1, 2014, and to all other restaurants from January 1, 2015. In addition, smoking has been prohibited in internet cafés from June 1, 2013. However, indoor public places and workplaces such as karaoke bars and traditional bars and pubs are not included in the list of facilities that are required to implement a prohibition on smoking, in spite of the extremely high smoking prevalence in these settings.

Further studies are needed to evaluate the effects of the 2010 amendment to the National Health Promotion Act, and to provide evidence for developing and promoting stronger smoke-free policies.

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