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Original Investigation

Exposure to Particulate Matters ($PM_{2.5}$) and Airborne Nicotine in Computer Game Rooms After Implementation of Smoke-Free Legislation in South Korea

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Abstract

Introduction: In South Korea, computer game rooms are subject to regulations mandating a designated nonsmoking area pursuant to Article 7 of the Enforcement Rules of the National Health Promotion Act; nonsmoking areas must be enclosed on all sides by solid and impermeable partitions.

Methods: Using $PM_{2.5}$ monitors (SidePak AM510) and airborne nicotine monitors, we measured concentrations in smoking and nonsmoking areas to examine whether separation of the nonsmoking areas as currently practiced is a viable way to protect the nonsmoking area from secondhand smoke exposure. Convenient samplings were conducted at 28 computer game rooms randomly selected from 14 districts in Seoul, South Korea between August and September 2009.

Results: The medians (interquartile range) of $PM_{2.5}$ concentrations in smoking and nonsmoking areas were 69.3 μg/m^3 (34.5–116.5 μg/m^3) and 34 μg/m^3 (15.0–57.0 μg/m^3), while those of airborne nicotine were 0.41 μg/m^3 (0.25–0.69 μg/m^3) and 0.12 μg/m^3 (0.06–0.16 μg/m^3), respectively. Concentrations of airborne nicotine and $PM_{2.5}$ in nonsmoking areas were substantially positively associated with those in smoking areas. The Spearman correlation coefficients for them were 0.68 (p = .02) and 0.1 (p = 0.7), respectively. According to our modeling result, unit increase of airborne nicotine concentration in a smoking area contributed to 7 (95% *CI* = 2.5–19.8) times increase of the concentration in the adjacent nonsmoking area after controlling for the degree of partition left closed and the indoor space volume.

Conclusions: Our study thus provides evidence for the introduction of more rigorous policy initiatives aimed at encouraging a complete smoking ban in such venues.

Introduction

Exposure to secondhand smoke (SHS) is a worldwide public health problem (California Environmental Protection Agency, 2005; International Agency for Research on Cancer [IARC], 1986, 2002; National Research Council, 1986; U.S. Department of Health and Human Services [USDHHS], 1986, 2006; U.S. Environmental Protection Agency [USEPA], 1992). In 2002, the IARC concluded that "involuntary smokers are exposed to the same numerous carcinogens and toxic substances that are present in tobacco smoke produced by active smoking, which is the principal cause of lung cancer." Recently, the USDHHS (2006) reported that "scientific evidence indicates that there is no risk-free level of exposure to SHS."

In South Korea, Article 7 of the Enforcement Rules of the National Health Promotion Act was passed in 2003. Under these rules, smoking has been banned in "public places," that is, schools, hospitals, and airports, etc. Article 7 further states that "commercial hospitality venues" must designate a nonsmoking area, constituting up to half of the entire space of the venue, which must be enclosed on all sides by solid and impermeable partition walls and be separated from the smoking area. However, in reality, such areas are not completely segregated due to the existence of a doorway on the partition wall connecting the smoking and nonsmoking areas. Thus, it is anticipated that air quality in nonsmoking areas may be affected by that of smoking areas.

A large number of previous studies reported that young children were among the most vulnerable population for adverse effects from SHS exposure (Matt, Bernert, & Hovell, 2008). In South Korea, this is particularly relevant in facilities where children and adolescents play computer games (Stewart & Choi, 2003). "Computer game rooms" in South Korea are commercial facilities providing patrons with high-performance

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personal computers and high-speed Internet access where patrons can play network games either in smoking or in nonsmoking areas divided by partition walls. Such computer game rooms were originally invented in South Korea and are currently spreading throughout many countries. More than 21,000 game rooms were open in Korea as of December 2008 (Ministry of Culture, Sports, and Tourism, South Korea, 2009). Regular patrons, typically adolescents and young adults, spend approximately 2 hr daily in the computer game rooms (Kim, 2002). Therefore, it is likely that the nonsmoking adolescent patrons of the computer game rooms have been chronically exposed to SHS. A large number of previous studies reported exposure levels of SHS in smoking and nonsmoking areas of hospitality venues and workplaces (Chiu et al., 2010; Lopez et al., 2008; Lung, Wu, & Lin, 2004). However, limited information is available on indoor SHS levels in computer game rooms. And few studies have evaluated the effectiveness of the partition walls pursuant to Article 7 of the Enforcement Rules of the National Health Promotion Act.

This study was aimed at assessing the levels of two indoor SHS exposure markers, that is, $PM_{2.5}$ (particulate matter of 2.5 µm or less in aerodynamic diameter) and airborne nicotine concentrations, in computer game rooms with various degrees of partition left closed (%). Then, we evaluated whether physically separating nonsmoking areas from smoking areas using partition walls pursuant to the enforcement rules is a viable approach to protect the air quality of nonsmoking areas from SHS exposure.

Methods

Study Sites

This pilot study was designed as a cross-sectional study. Samples were collected in 28 computer game rooms randomly selected from 14 districts of Seoul, the capital of South Korea. The game rooms were selected from on a telephone book by our study assistant. We visited two game rooms in a district between August and September 2009. In the 28 computer game rooms, we conducted real-time $PM_{2.5}$ monitoring (n = 28) and airborne nicotine sampling (n = 18). Though nonsmoking areas must be completely separated from smoking areas under the law, separation was not complete in most facilities due to incomplete barrier from floor to ceiling and/or a corridor without any sliding or hinged door on the partition wall between the two areas. We calculated the degree of a partition left closed (%) by subtracting the surface area of any openings from the total surface area of entire partition wall between the two areas and then dividing it by the total surface area (Equation 1). The total number of occupants, the number of cigarette butts, the material and type of the wall, the indoor volume, and the presence of air conditioners and ventilators were noted. The location of each sampler was also marked on a diagram.

$$\text{Partition left closed (\%)} = \frac{\begin{pmatrix}\text{Total surface area}\\ \text{of the wall}\end{pmatrix} - \begin{pmatrix}\text{Surface area of any}\\ \text{openings therein}\end{pmatrix}}{(\text{Total surface area of the wall})} \times 100. \quad (1)$$

Measurements of PM2.5 and Airborne Nicotine

Measurement of $PM_{2.5}$ levels was conducted using a battery-operated real-time aerosol monitor (Sidepak AM510; TSI, Shoreview, MN). The monitor determines the mass concentration by the intensity of scattered laser light. As the light scattering properties of particles differed according to the size and composition of particles, it is necessary to calibrate the measurement results of the monitor. We used 0.3 as a correction factor for measurements. The correction factor was selected from previously reported papers (Lee et al., 2008; Repace, 2006; Semple et al., 2007). Every afternoon prior to $PM_{2.5}$ monitoring, we performed zero calibration and checked the flow rate (1.7 L/min). Since most computer game rooms are occupied by young patrons from the late afternoon, we conducted monitoring mainly from 4 to 6 p.m.

The monitor was set to record $PM_{2.5}$ concentrations every 10 s. At each computer game room, monitors were installed at the outside entrance of the computer game room, inside the smoking area, inside the nonsmoking area, and at the outside entrance for 5, 20, 20, and 5 min consecutively. Monitoring was conducted inconspicuously in order not to disturb the users' normal behaviors. Each monitor was hidden inside a backpack, which was placed on the central computer table in the smoking and nonsmoking areas. The inlet of the monitor was attached with a short length of Tygon tube and left protruding outside. To minimize the effect of additional source contribution to our $PM_{2.5}$ measurement results, we reported our $PM_{2.5}$ results after subtracting the field background $PM_{2.5}$ concentrations measured at the outside entrance of the computer game rooms. After completion of first phase monitoring, $PM_{2.5}$ monitors in smoking and nonsmoking areas were exchanged for another 20 min of monitoring in both areas. By doing so, 70% $PM_{2.5}$ monitoring was conducted in duplicate. We calculated a limit of detection (LOD) by multiplying a *SD* obtained from eight blank sampling (measurements in eight clean nonsmoking offices using method described as above) and the student's t value appropriate for a 99% confidence level with n – 1 *df*.

As seven computer game rooms had high field background levels that were larger than the levels in nonsmoking areas, after the subtraction of field background levels from each measurement, 21 nonsmoking and 28 smoking area results were used for our data analysis. Airborne nicotine was measured using passive samplers (Hammond & Leaderer, 1987). Two samplers were installed on the central computer tables inside the smoking and nonsmoking areas after we initiated the real-time $PM_{2.5}$ monitoring. The passive airborne nicotine samplers were collected 7 days after installation. For quality control, 50% of samples were measured in duplicate. Collected samples were analyzed using gas chromatography–mass spectrometry (GC–MS, Agilent Technology 6890N, 5973) coupled with a capillary column (DB-5, 30 m 0.25 mm; film thickness 0.25 mm; J and W Scientific, Folsom, CA) with minor modification of nicotine analysis methods as developed by Kim, Wipfli, Avila-Tang, et al. (2009) and Kim, Wipfli, Navas-Acien, et al. (2009). GC oven temperature was kept at 50 °C for 1 min and then ramped to 290 °C by 25 °C/min and held for 2 min. Nicotine and Nicotine-d3, internal standard, were separated and detected in single ion monitoring (SIM) mode using m/z 84, 162 and m/z 87, 165, respectively. Using the similar way as we applied for $PM_{2.5}$ results, we calculated the LOD for airborne nicotine with eight blank samples (containing the lowest level of nicotine calibration standard spiked on clean filters and then extracted using method described as above). Field background samples (n = 7) were collected to subtract background concentrations from measurements. Eighteen nonsmoking and smoking sample sets were used for data analysis.

Statistical Analysis

The statistical package of SAS was used for statistical analyses. We conducted the Spearman correlation test to evaluate the associations among the number of smokers, the number of cigarettes butts, $PM_{2.5}$ concentrations, and air nicotine concentrations in smoking areas as some variables were not normally distributed. We calculated ratios (NS/S, %) of $PM_{2.5}$ and airborne nicotine concentrations in nonsmoking (NS) to smoking (S) areas to evaluate the effectiveness of a partition wall between the two areas. Then, we compared the distribution of ratios of concentrations of each pollutant obtained from the game rooms with a high degree of partition left closed (≥77%) to the ones with a low degree of partition left closed (<77%) with respect to the median of the degree of partition left closed distribution, using the Wilcoxon's rank sum test since the distribution of the ratio was not normally distributed. Finally, we evaluated the associations of air nicotine concentrations in nonsmoking areas with those in corresponding smoking areas after adjusting for the degree of partition left closed (%) and indoor space volume (cubic meters) using multivariate linear regression models (Tabachnick & Fidell, 2001). Log transformation was applied to the measurements of airborne nicotine in the models because distribution of dependent variable was not normally distributed.

Results

Area Sampling Results

All computer game rooms had nonsmoking areas, which were separated from smoking areas with various degrees of partition left closed from 33% to 100%. The median (interquartile range, IQR) of the numbers of occupants in smoking areas was 18 (13–23) and that in nonsmoking areas was 11 (8–14). In the smoking area, the IQR of the number of cigarette butts was from 21 to 72, while no cigarette butts were found in nonsmoking areas. Other characteristics of each computer game room are summarized in Table 1.

The LOD for SidePak $PM_{2.5}$ monitor was 2.3 μg/m^3 and that of nicotine in air was 0.003 μg/m^3 for a 7-day air sample. Accuracy of analysis for seven replicate of 2.5 ng nicotine standard samples was 91% (2.28 ± 0.34 ng) and precision calculated by relative *SD* was 15%.

The medians (IQR) of $PM_{2.5}$ concentrations in smoking and nonsmoking areas were 69.5 μg/m^3 (34.5–116.5 μg/m^3) and 34.0 μg/m^3 (15.0–57.0 μg/m^3), respectively, after subtracting background $PM_{2.5}$ concentrations. The medians (IQR) of airborne nicotine concentrations in smoking and nonsmoking rooms were 0.41 μg/m^3 (0.25–0.69 μg/m^3) and 0.12 μg/m^3 (0.06–0.16 μg/m^3), respectively. The median (IQR) of the NS/S ratio of $PM_{2.5}$ concentration was 50% (IQR: 23.5%–77.6%) and that for airborne nicotine was 27.4% (IQR: 17.1%–55.3%).

According to the Spearman test, in smoking areas, the number of smokers showed a mild association (r = .48, n = 28, p = .01) with the number of cigarette butts. The number of cigarette butts showed a stronger association with air nicotine concentrations (r = .61, n = 18, p = 0.01) than $PM_{2.5}$ concentrations (r = .43, n = 28, p = .02). Airborne nicotine concentrations were positively associated (r = 0.44, n = 18) with $PM_{2.5}$ concentration, but this was not statistically significant (p = 0.06; (Table 2).

Effectiveness of Partition Walls

The results of the Spearman correlation tests showed an opposite associations of the ratios (NS/S) of concentrations in nonsmoking (NS) to smoking (S) with the degree of partition left closed (r = –.33 for $PM_{2.5}$ and r = –.23 for nicotine) between the two areas. However, the associations were not statistically significant (p = .14 and .35 respectively). We then compared the distributions of the ratios (NS/S) of two groups: the high separation group (degree of partition left closed ≥77%) and the other group (<77%), with respect to the median of the separation rate distribution (Figure 1). The Wilcoxon's rank sum test result indicated that the distributions were not significantly different (p = .24 for $PM_{2.5}$ and .41 for airborne nicotine) between the two separation groups.

Concentrations of airborne nicotine and $PM_{2.5}$ in nonsmoking areas were substantially positively associated with those in smoking areas (Table 2). The Spearman correlation coefficients for nicotine and $PM_{2.5}$ were 0.68 (n = 17, p = .02) and 0.1 (n = 23, p = .7), respectively. The positive association between smoking and nonsmoking areas was not changed even after controlling for the degree of partition left closed and the indoor space volume (Table 3). Unit increase of airborne nicotine concentration in a smoking area contributed to seven (95% *CI* = 2.5–19.8) times increase of the concentration in the adjacent nonsmoking area.

Discussion

In the presence of smokers, nonsmokers inhale secondhand tobacco smoke (SHS), a combination of sidestream smoke released from the cigarette's burning and mainstream smoke exhaled by the active smoker (Guerin, Jenkins, & Tomkins, 1992). Culturally, smoking among Korean men is still a socially sanctioned behavior in many indoor workplaces and commercial hospitality venues, including bars, nightclubs, restaurants, and computer game rooms.

Our study indicated that contamination levels of indoor air quality in computer game rooms in Seoul were quite significant. The median $PM_{2.5}$ level was 69 μg/m^3 in smoking areas. This level was about two times higher than the 24-hr $PM_{2.5}$ standard (35 μg/m^3) in National Ambient Air Quality Standard (NAAQS; USEPA, 2010). The NAAQS is a reference for comparison in the absence of standards for indoor air quality. The indoor $PM_{2.5}$ level in 75% of the smoking area exceeded the standard. Even though no smoking was observed in the nonsmoking area, the indoor $PM_{2.5}$ level in 39% of the nonsmoking area exceeded the standard.

The median (69 μg/m^3) of $PM_{2.5}$ concentrations in the smoking area of our study was half of the value (150 μg/m^3) obtained from a casino located in East St. Louis, IL (Travers, 2007). In addition, our results were comparable with a previous

Table 1. Descriptive Information for Computer Game Rooms and $PM_{2.5}$ and Airborne Nicotine Concentrations

No.	# of patrons		# of cigarette butts (S)	Separation rate (%)	# of ventilation fan	Indoor area volume (m^3)	$PM_{2.5}$			Airborne nicotine ($\mu g/m^3$)		
	NS	S					NS ($\mu g/m^3$)	S ($\mu g/m^3$)	NS/S (%)	NS ($\mu g/m^3$)	S ($\mu g/m^3$)	NS/S (%)
1	13	12	23	100	3	454	7	82	8.5	0.15	0.41	36.6
2	26	18	5	100	2	206	<BG	3	NA	NA	NA	NA
3	8	5	10	100	—	330	5	38	13.2	0.06	0.40	15.0
4	5	14	60	90	—	248	15	30	50.0	0.15	0.49	30.6
5	12	20	100	90	—	413	8	269	3.0	NA	NA	NA
6	14	23	92	90	—	578	79	132	59.8	0.12	0.93	12.9
7	9	23	69	88	—	413	109	74	147.3	0.10	Lost	NA
8	12	15	7	87.5	2	413	<BG	245	NA	NA	NA	NA
9	14	9	54	85	—	371	61	101	60.4	0.12	0.18	66.7
10	11	16	96	80	—	495	2	234	0.9	0.14	0.69	20.3
11	18	24	96	80	—	660	42	178	23.6	0.28	1.00	28.0
12	10	17	68	80	—	371	54	48	112.5	0.16	0.88	18.2
13	10	5	6	80	—	289	<BG	12	NA	0.04	0.15	26.7
14	3	19	55	78	—	495	<BG	1	NA	NA	NA	NA
15	23	22	66	76	—	330	30	97	30.9	NA	NA	NA
16	13	13	52	75	—	660	70	142	49.3	0.04	0.25	16.0
17	9	7	35	75	—	454	57	76	75.0	0.52	0.95	54.7
18	4	9	18	72	—	413	24	34	70.6	0.12	0.19	63.2
19	15	23	6	67	8	248	<BG	89	NA	NA	NA	NA
20	13	32	30	66	6	536	3	1	NA	0.04	0.25	16.0
21	8	24	96	66	—	413	20	85	23.5	0.06	0.35	17.1
22	8	15	45	66	—	330	38	49	77.6	0.14	0.47	29.8
23	9	19	5	66	3	206	37	37	100	NA	NA	NA
24	9	7	35	50	—	495	16	65	24.6	0.17	0.32	53.1
25	2	26	104	50	—	371	44	35	125.7	NA	NA	NA
26	16	25	75	45	—	660	16	151	10.6	0.11	0.43	25.6
27	5	22	30	40	8	371	<BG	2	NA	NA	NA	NA
28	16	14	23	33	3	330	63	45	140	0.17	0.17	100
N	28	28	28	28	8	28	22	28	21	19	18	18
Median	10.5	17.5	48.5	77	3	413	34	69.5	50	0.12	0.41	27.4
IQR	8–14	12.5–23	20.5–72	66–88	2.5–7	330–495	15–57	34.5–116.5	23.5–77.6	0.06–0.16	0.25–0.69	17.1–53.1

Note. BG = Background; Lost = sample lost; NA = not available; NS = nonsmoking area; S = smoking area .

Table 2. Spearman Correlation Coefficients Among Number of Smokers, Cigarette Butts, Airborne Nicotine Concentrations, and $PM_{2.5}$ Concentrations Measured in Smoking Areas of Computer Game Rooms and the Coefficients for $PM_{2.5}$ and Airborne Nicotine Concentrations Measured in Nonsmoking and Smoking Areas

	1	2	3	4	5	6
Number of smokers in smoking rooms	1.00 (28)					
Number of butts in smoking rooms	0.48[a] (28)	1.00 (28)				
Concentration of Nicotine in smoking room	0.37 (18)	0.61[a] (18)	1.00 (18)			
Concentration of Nicotine in nonsmoking rooms	−0.10 (19)	0.13 (19)	0.52[a] (18)	1.00 (19)		
Concentration of $PM_{2.5}$ in smoking rooms	0.98 (28)	0.43[a] (28)	0.44 (18)	0.16 (19)	1.00 (28)	
Concentration of $PM_{2.5}$ in nonsmoking rooms	0.03 (22)	0.10 (22)	−0.01 (17)	0.08 (18)	0.08 (22)	1.00 (22)

Note. [a]Statistically significant at the significance level of 0.05. The numbers in the parentheses are the numbers of observations.

study done at smoking places (bars, restaurants, retail outlets, airports, etc) in Asia: 102 μg/m³ in Malaysia, 164 μg/m³ in Malaysia, and 197 μg/m³ in China (Hyland, Travers, Dresler, Higbee, & Cummings, 2008). Similarly, the average $PM_{2.5}$ concentrations of seven Kentucky communities ranged from 67 to 304 μg/m³ before smoke-free laws were enacted (Lee et al., 2009). Our median concentration of $PM_{2.5}$ in smoking areas was consistent with results reported by Van Deusen et al. (2009) (84 μg/m³), while our value (37 μg/m³) in nonsmoking area was about four times higher than their value (9 μg/m³). Also, our median value for nonsmoking area was slightly higher than the values obtained from nonsmoking indoor public places of other countries (Ireland at 22, Uruguay at 18, and New Zealand at 8 μg/m³; Hyland et al., 2008). However, a lack of quantitative information on background concentration levels and degree of partition left closed in other studies limits further exploration of the basis for the differences in distributions of ratios (NS/S) between our study and their studies.

We compared airborne nicotine measurement results from our study to those results measured at smoking-allowed bars and nightclubs in seven South American countries (Navas-Acien et al., 2004) and at homes in 31 countries (Wipfli et al., 2008), which used the same method that we applied in this study. Our medians (0.41 and 0.12 μg/m³) of airborne nicotine concentrations in smoking and nonsmoking areas were slightly lower than the median values reported by Navas-Acien (1.24 μg/m³) but higher than the median values measured in 31 countries (0.17 μg/m³ for smoking households and 0.01 μg/m³ for nonsmoking households).

Alevantis et al. (2003) reported that "operating swing-type entry doors to smoking rooms results in pumping up to 10% of smoking room air into adjoining nonsmoking areas even when smoking room areas were maintained under negative pressure." Invernizzi, Ruprecht, Mazza, Marco, and Boffi (2004) also reported that nonsmoking coaches, separated from the adjacent smoking carriages by automatic sliding doors, could not protect occupants from SHS exposure even if each coach was equipped with a separate HVAC (heat, ventilation, and air conditioning) system. In our study, the IQR of ratios (NS/S, %) of $PM_{2.5}$ and air nicotine were ranged from 23.5 to 77.6 and from 17.1 to 55.3, respectively. Although the absolute value of air nicotine concentrations for smoking and nonsmoking areas was about 10 times lower, compared with Lopez et al.'s results, our median (28%) of the ratios (NS/S) was comparable with theirs (32%).

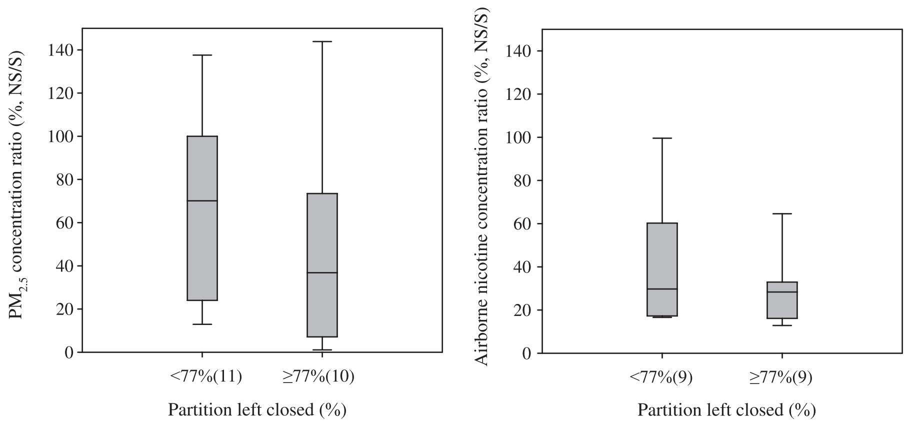

Figure 1. Distribution of ratios of $PM_{2.5}$ and airborne nicotine concentrations in nonsmoking area (NS) to smoking areas (S) by categories of degree of partition left closed of partition walls between the two areas (The number in parentheses is the sample size for each category. Two groups were established according to the median value (78%) of the degree of partition left closed. Box plots show the median as a center bar, the 25th and 75th percentiles as a box, and the 5th and 95th percentile values as whiskers.).

Table 3. GMs and GMRs of Airborne Nicotine Concentrations in Nonsmoking Areas by Unit Increase in Smoking Area

	Airborne nicotine (μg/m^3)			
	Crude (R^2 = 0.39)		Adjusted[a] (R^2 = .54)	
	Nonsmoking area, GM (*p* value)	GMR (95% *CI*)	Nonsmoking area, GM (*p* value)	GMR (95% *CI*)
		1.00 (Reference)		1.00 (Reference)
Unit increase (μg/m^3) in smoking area	0.46 (0.005)	4.34 (1.65–11.4)	0.73 (0.001)	7.04 (2.51–19.8)

Note. GM = geometric mean; GMR = geometric mean ratio.
[a]Adjusted for continuous variables of degree of partition left closed (%) and indoor space volume (m^3).

Lopez et al. measured air nicotine concentrations in hospitality venues of European countries where no national smoking regulations were implemented at the time of the study. Consistent with other earlier studies (Brennan et al., 2010; Lee et al., 2008; Liu, Alevantis, & Offermann, 2001; Travers, 2007), $PM_{2.5}$ and airborne nicotine in nonsmoking areas were likely detected due to SHS drifting through doorways on partition walls from smoking area. Our results indicated that nonsmoking young patrons thus would not be protected from SHS exposure even in nonsmoking areas.

Despite growing public and political interest in enacting smoke-free regulations in South Korea, computer game rooms and other hospitality venues still face challenges in providing clean indoor air. Under global efforts to reduce the burden of SHS exposure and tobacco use led by the Framework Convention on Tobacco Control (Roemer, Taylor, & Lariviere, 2005; Taylor & Bettcher, 2000), the Korean Ministry for Health, Welfare, and Family Affairs has implemented smoking restrictions in public places, including schools and hospitals. However, additional immediate actions are needed to protect nonsmoking persons from unwanted exposure to SHS in hospitality venues (Samet & Wipfli, 2009). Such establishments are of particular interest in antismoking legislation as some hospitality venues allow adolescents enter. In South Korea, a large number of young adolescents spend approximately 2 hr per day in computer game rooms (Kim, 2002). Being subject to chronic exposure to SHS in such places can be a significant health problem for nonsmoking young adolescents (Tyc, Hovell, & Winickoff, 2008).

Our study results implied that legislation, allowing partition walls with a doorway, inadequately protected the air quality of nonsmoking areas. The Korean Ministry for Health, Welfare, and Family Affairs should thus change Article 7 of the Enforcement Rules of the National Health Promotion Act to implement complete indoor smoking bans to make the environment around nonsmoking users smoke free.

To our knowledge, this study is the first study evaluating quantitatively the effectiveness of a partition wall and implementation of separate nonsmoking areas in computer game rooms. We understand that sources of indoor $PM_{2.5}$ can be varied, including industry, polluted soil, motor vehicles, and cooking activities (Pekey et al., 2009). To minimize the effect of additional source contribution to our $PM_{2.5}$ measurement results, we used our $PM_{2.5}$ indoor measurement results after subtracting background $PM_{2.5}$ concentrations measured at the outside entrances of the computer game rooms. In addition, we measured a direct SHS marker, airborne nicotine, as well. However, this study has some limitations. First, the sample size of our study was relatively small. Nevertheless, we randomly selected 28 computer game rooms (2 per district) located in regions with various socioeconomic levels, the distributions of concentrations would not be systematically biased. Increasing sample size in future studies will help us conduct a better estimation on the association of air quality of nonsmoking rooms with the degree of partition left closed. Second, airborne nicotine concentrations might be underestimated since we included morning time periods when nicotine levels were low due to lack of patrons in the game rooms and daily floor cleaning activities, including sweeping and/or scrubbing. If sampling were conducted only at day peak time period, 7-day nicotine concentrations should be much higher. Third, the monitoring time for $PM_{2.5}$ was relatively short compared with that of airborne nicotine. Therefore, the concentration of $PM_{2.5}$ might vary depending on the monitoring time selected. Forth, we could not measure air exchange or ventilation rates due to limited study period and research grant. In the future study, measurement of the ventilation and/or air exchange rates will improve information on the partition rate between the smoking and nonsmoking areas.

In summary, our study will strengthen and motivate implementation of a complete smoking ban in many workplaces and hospitality venues that are currently regulated by a partial smoke-free law or provisions for spatial separation through a partition. Our study provides compelling evidence for the support of more rigorous policy initiatives aimed at encouraging a complete smoking ban and reducing SHS in such venues.

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Declaration of Interests

None declared.

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