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Health impact of a smoke free policy in small indoor sports facilities in Seoul: Workers' subjective symptoms and indoor air related job environment in billiard halls and screen golf clubs

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ABSTRACT

Introduction: This study aimed to evaluate the health impact of a smoke free policy implemented in these facilities in the Seoul metropolitan area, focusing on workers' subjective symptoms in relation to indoor air related job environment.

Materials and methods: Cross-sectional surveys were conducted among 589 workers employed in billiard halls and screen golf clubs located in Seoul in August 2017 (before policy implementation) and August 2018 (after implementation). Associations between job environment factors and work time symptoms were examined using chi-squared tests or Fisher's exact tests and multivariable logistic regression, sequentially adjusting for general and work related characteristics. Across all symptoms, survey year (2018 vs. 2017) was consistently associated with reduced odds of symptom complaints.

Results: Facilities operating mechanical ventilation only or combined natural and mechanical ventilation showed significantly lower odds of all symptoms than those relying solely on natural ventilation. In contrast, workers in facilities with a higher number of windows, facilities where cooking was conducted, or those with more smoking customers generally reported higher odds of symptoms. More frequent ventilation (≥5 times per day) tended to reduce respiratory complaints, whereas insufficient or intermittent ventilation was associated with higher symptom prevalence.

Conclusion: Smoke free regulations, appropriate mechanical ventilation and comprehensive indoor air quality management, including control of cooking and outdoor pollutant infiltration, are needed to further protect the health of workers in these environments. These findings support comprehensive indoor air quality management combining smoke-free policies with adequate mechanical ventilation systems in small indoor sports facilities.

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Introduction

Small-scale service workers, such as cashiers at franchise markets, cooks in small restaurants, moving company workers, and delivery drivers, frequently work in workplaces with fewer than five employees and often under precarious employment conditions, including temporary work and self-employment, which account for over half of this labor sector [1]. Among small-scale sports facilities, billiard halls and golf practice ranges have been identified as sectors where safety inspections and environmental management are inadequately implemented, and there is growing concern regarding their poor indoor environments and the need for systematic evaluation and control [2]. In South Korea, a smoke-free policy for indoor sports facilities, including billiard halls and screen golf clubs, was implemented on 3 december 2017 under the national health promotion act, designating these places as non-smoking areas. Although prior studies have investigated indoor air quality (e.g., particulate matter, volatile organic compounds, nicotine) and health effects in smoking-allowed buildings, only a few have focused specifically on indoor sports facilities, and even fewer have analyzed health effects according to facility and ventilation characteristics [3-5]. Furthermore, indoor air quality in these facilities can be influenced by building type, construction year, and structural characteristics around ventilation openings, which can modulate exposure to indoor and outdoor pollutants [6, 7].

Billiard halls typically consist of large open spaces where workers and customers share the same air volume, meaning that any smoking or pollutant-generating activities in the playing area can directly affect workers. In contrast, screen golf clubs are often divided into multiple independent rooms, which may reduce the transport of pollutants such as particulate matter from customer areas to worker zones such as the lobby [3, 7]. Previous measurements have shown that levels of PM_{10} and $PM_{2.5}$ in screen golf clubs tend to be lower than those in billiard halls [3, 5]. Nonetheless, workers in both facility types can be exposed to complex mixtures of pollutants, including particulate matter, nicotine, VOCs, nitrogen dioxide, and combustion products, which are known to cause respiratory and sensory symptoms and to increase the risk of chronic diseases [8]. International evidence indicates that implementation of smoke-free policies in hospitality and recreational settings leads to reductions in respiratory and sensory symptoms among workers, and decreases in exposure to secondhand smoke and related carcinogens such as benzene [9-11]. However, empirical evidence on the health impact of smoke-free policies specifically in small indoor sports facilities is limited in Korea. Moreover, understanding how facility characteristics (e.g., location, cooking practices, number of windows) and ventilation features (e.g., type, frequency, and duration of ventilation) modify these health impacts is essential for designing effective indoor air quality management strategies.

Therefore, this study aimed to (1) evaluate changes in workers' subjective respiratory and sensory symptoms before and after the implementation of a smoke-free policy in billiard halls and screen golf clubs in selected districts of Seoul, and (2) identify key job environment factors related to indoor air quality-especially facility and ventilation characteristics—that are associated with these symptoms. Findings from this study are intended to provide scientific evidence on the health impact of the smoke-free policy and to inform integrated air quality management strategies for small indoor sports facilities.

Materials and methods

Study setting and participants

A cross-sectional survey was conducted among

workers in billiard halls and screen golf clubs located in three districts (Seocho, Songpa, and Nowon) of Seoul, South Korea. The surveys were administered twice: in August 2017 (pre policy implementation) and in August 2018 (post policy implementation). Workers aged 19 years or older, employed in billiard halls or screen golf clubs in the target districts, were eligible to participate. Facilities were selected considering district-level similarities to overall Seoul averages with respect to health behaviors, living environment, and income level, in order to enhance representativeness and comparability across districts. A total of 589 workers were included in the final analysis after excluding those with unreliable responses (e.g., incomplete key items, unrealistically short response times) or missing answers to crucial questions such as ventilation time. Data collection was conducted via face-to-face visits, and participants completed self-administered questionnaires designed to capture both health symptoms and job environment characteristics. Symptoms were dichotomized into present ("often" or "sometimes") and absent ("never"), and symptom severity was not separately captured. Baseline characteristics were compared between the 2017 and 2018 survey samples to assess their comparability (Table 1). The distributions of major demographic and work-related characteristics were broadly similar across the two years, although some differences in symptom prevalence and job-environment characteristics were observed. The same survey procedures and questionnaire were applied in both years, and workers were recruited through field visits to eligible facilities in the same three districts. Although selection bias cannot be completely ruled out, these procedures help support comparability between the two cross-sectional samples.

Table 1. Baseline characteristics and prevalence of work-time symptoms

Variable	Total N (%)	Cough N (%)	Eye irritation/pain N (%)	Facial flushing/headache N (%)
Total	589 (100.0)	239 (40.6)	150 (25.5)	100 (17.0)
Facility type				
Billiard hall	397 (67.4)	186 (46.9)	102 (25.7)	70 (17.6)
Screen golf club	192 (32.6)	53 (27.6)	48 (25.0)	30 (15.6)
District				
Seocho-gu	197 (33.4)	61 (31.0)	40 (20.3)	27 (13.7)
Songpa-gu	199 (33.8)	106 (55.3)	56 (28.1)	22 (11.1)
Nown-gu	193 (32.8)	72 (37.3)	54 (28.0)	51 (26.4)
Sex				
Male	442 (75.0)	172 (38.9)	104 (23.5)	72 (16.3)

Table 1. Continued

Variable	Total N (%)	Cough N (%)	Eye irritation/pain N (%)	Facial flushing/headache N (%)
Male	442 (75.0)	172 (38.9)	104 (23.5)	72 (16.3)
Female	147 (25.0)	67 (45.6)	46 (31.3)	28 (19.0)
Age group				
20s	30 (5.1)	10 (33.3)	8 (26.7)	6 (20.0)
30s	54 (9.2)	22 (40.7)	15 (27.8)	7 (13.0)
40s	163 (27.7)	67 (41.1)	48 (29.4)	29 (17.8)-
50s	243 (41.3)	99 (40.7)	61 (25.1)	41 (16.9)
≥ 60s	99 (16.8)	41 (41.4)	18 (18.2)	17 (17.2)
Education				
≤ High school	229 (38.9)	99 (43.2)	50 (21.8)	27 (11.8)
University	341 (57.9)	128 (37.5)	91 (26.7)	65 (19.1)
Graduate school	19 (3.2)	12 (63.2)	9 (47.4)	8 (42.1)
Self-rated health				
Poor	14 (2.4)	8 (57.1)	7 (50.0)	4 (28.6)

Measures (Outcome variables: subjective symptoms during working hours)

Subjective health symptoms during working hours were assessed using five items representing respiratory and sensory/skin complaints: cough, phlegm, eye irritation/pain, skin itching, and facial flushing/headache. Each symptom was recorded on a 3-point scale: "often," "sometimes," and "never." For analysis, workers who responded "often" or "sometimes" to a given symptom were classified as having that symptom during working hours, whereas those who responded "never" were classified as not having the symptom. For brevity and focus, this paper emphasizes three representative symptoms: cough, eye irritation/pain, and facial flushing/headache, which showed clear associations with smoke-free policy implementation and job environment factors.

Explanatory variables were grouped into general characteristics, work characteristics, facility characteristics, and ventilation characteristics. General characteristics included facility type (billiard hall vs. screen golf club), survey

district (Seocho-gu, Songpa-gu, Nowon-gu), sex (male vs. female), age group, body mass index (BMI), marital status (married vs. unmarried), educational level (≤high school, university, graduate school), self-rated health (poor/fair vs. good), quality of life (poor/fair vs. good), smoking history (ever vs. never), and survey year (2017 pre-policy vs. 2018 post-policy). Work characteristics comprised employment status (owner/self-employed vs. employee), years of employment (<1 year, 1-5 years, 5-10 years, ≥10 years), and daily hours spent at the facility (<10 h, 10-15 h, ≥15 h). Facility characteristics encompassed daily customer volume, number of smoking customers (<10, 10-30, 30-50, ≥50), average customer stay duration (<1 h, 1-2 h, ≥2 hours), facility location (above-ground vs. basement), presence of designated smoking room (yes vs. no), air purifier availability (yes vs. no), and indoor cooking practices (yes vs. no). "Air purifier availability" indicated the presence of an air purifier in the facility, not confirmed operational use. Symptoms were dichotomized into present ("often" or "sometimes") and absent ("never"), and symptom severity was not separately captured.

Ventilation characteristics included number of windows (0-3, 3-5, ≥5), daily ventilation frequency (none, 1-2 times, 3-4 times, ≥5 times), total daily ventilation duration (<30 min, 30 min-1 h, 1-2 h, ≥2 h), and ventilation type categorized as natural ventilation only, mechanical/central ventilation only, or combined natural and mechanical ventilation.

Statistical analysis

Data were coded and entered according to a predefined coding guide. Descriptive statistics were used to summarize the distribution of variables, and outliers or inconsistent responses were identified and handled prior to inferential analysis. Associations between subjective symptoms and each explanatory variable were initially examined using chi-squared tests or Fisher's exact tests, as appropriate.

To explore factors associated with the presence of each symptom during working hours, multivariable logistic regression models were specified a priori based on conceptual relevance and prior evidence rather than univariate p-value screening alone. Covariates were selected to control for potential confounding across four domains: general characteristics (e.g., facility type, district, sex, age, education, smoking history, survey year), work-related factors (e.g., employment status, employment duration, working hours), facility-related characteristics (e.g., smoking customers, air purifier availability, cooking inside the facility), and ventilation-related characteristics (e.g., ventilation type, frequency, and duration). Variables with strong theoretical relevance or known associations with symptom outcomes were retained in the models regardless of their univariate significance. Missing data were handled by excluding records with missing values for variables required in the fully adjusted models; because the proportion of missingness was small, complete-case analysis was considered appropriate. Variables with $p<0.05$ in univariate analyses were considered potential predictors and entered into the multivariable models. Analyses were performed using R (Version 4.0.2) and R studio (Version 1.3.1056). Statistical significance was defined as a two-sided p-value < 0.05.

Results and discussion

Participant characteristics and symptom prevalence

Among the 589 workers, 40.6% reported cough during working hours, 25.5% reported eye

irritation or pain, and 17.0% reported facial flushing or headache. The prevalence of these symptoms varied by facility type, district, sex, age group, education level, self-rated health, and survey year. For cough, workers in billiard halls reported symptoms more frequently than those in screen golf clubs (approximately 47% vs. 28% among those with cough complaints). Songpa district had the highest proportion of workers reporting cough, and women tended to report cough more than men. Workers with poorer self-rated health and those with lower quality of life also reported more cough. The proportion of workers without cough complaints was higher in 2018 than in 2017, indicating potential improvement after policy implementation. For eye irritation/pain, education level and survey year were significantly associated with symptom prevalence. Workers with higher education (graduate school) and those with poorer self-rated health tended to report more eye symptoms, while workers surveyed in 2018 were less likely to report these symptoms. For facial flushing/headache, district, education level, and survey year showed significant associations. Workers in Nowon district, those with higher education, and those with poorer health status had higher symptom prevalence, whereas the proportion of workers without these symptoms increased in 2018.

Factors associated with cough during working hours

In crude analyses (Model 1), the odds of reporting cough were significantly lower among screen golf club workers than among billiard hall workers (OR ≈ 0.43, 95% CI ≈ 0.30–0.63), among workers surveyed in 2018 compared with 2017 (OR ≈ 0.62, 95% CI ≈ 0.45–0.87), and among workers in facilities with mechanical or combined ventilation compared with natural ventilation only (OR range ≈ 0.38–0.47). In contrast, workers in Songpa district (vs. Seocho), those with longer working hours and years, those in facilities without air purifiers, facilities with more windows, certain intermediate ventilation frequencies, and longer but intermittent ventilation time had higher odds of cough. After adjustment for general characteristics (Model 2), screen golf club workers continued to show significantly reduced odds of cough (OR ≈ 0.33, 95% CI ≈ 0.21–0.51), and the 2018 survey remained associated with lower odds (OR ≈ 0.65, 95% CI ≈ 0.46–0.93). Mechanical and combined ventilation types were consistently protective (OR ≈ 0.43–0.46), while Songpa district, absence of air purifiers, a higher number of windows, and ventilation duration of 1–2 hours (vs. <30 min) were associated with higher odds of cough. In the fully adjusted model (Model 3), screen golf club employment was still associated with lower odds of cough (aOR ≈ 0.34, 95% CI ≈ 0.21–0.54), and mechanical or combined ventilation remained protective (aOR ≈ 0.42–0.46). Working in Songpa District and in facilities with more windows (≥3) remained positively associated with cough complaints. The association of survey year with cough weakened slightly and was no longer statistically significant at the 0.05 level, but the direction still suggested improvement after policy implementation.

Table 2. Multivariable logistic regression analysis for cough during working hours

Variable	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Survey year (ref.: 2017)			
2018	0.62 (0.45 – 0.87)	0.65 (0.46 – 0.93)	0.73 (0.51 – 1.06)
Facility type (ref.: Billiard hall)			
Screen golf club	0.43 (0.30 – 0.63)	0.43 (0.21 – 0.51)	0.34 (0.21 – 0.54)
District (ref.: Seocho-gu)			
Songpa-gu	2.54 (1.69 – 3.83)	2.70 (1.73 – 4.22)	2.86 (1.81 – 4.52)
Ventilation type (ref.: natural only)			
Mechanical/central	0.38 (0.24 – 0.58)	0.46 (0.28 – 0.75)	0.46 (0.28 – 0.77)
Natural + Mechanical	0.47 (0.27 – 0.80)	0.43 (0.24 – 0.78)	0.42 (0.23 – 0.77)
Air purifier (ref.: Yes)			
No	1.83 (1.30 – 2.58)	0.43 (1.01 – 2.24)	1.28 (0.86 – 1.91)
Number of windows (ref.: 0-3)			
3-5	2.40 (1.35 – 4.27)	2.04 (1.09 – 3.79)	2.14 (1.13 – 4.06)
≥ 5	2.51 (1.74 – 3.62)	1.75 (1.15 – 2.67)	1.74 (1.13 – 2.68)

*Model 1: Unadjusted; Model 2: Adjusted for general characteristics; Model 3: Fully adjusted for general and work characteristics. Bold = $p<0.05$

Factors associated with eye irritation/pain

In Model 1, eye irritation/pain during working hours was significantly less frequent in 2018 compared with 2017 (OR ≈ 0.21, 95% CI ≈ 0.14–0.32), and in facilities with designated smoking rooms and those operating mechanical or combined ventilation (OR ≈ 0.20–0.36) (Table 2). Higher education (graduate school), poorer self-rated health, longer years of employment, longer daily working hours, a higher number of smoking customers, more windows, greater ventilation frequency, and longer ventilation time were associated with higher odds of eye symptoms, suggesting complex interactions between ventilation practices, pollutant sources, and symptom perception. After adjusting for general characteristics (Model 2), the protective effect of the 2018 survey year (OR ≈ 0.22, 95% CI ≈ 0.14–0.33) and of mechanical or combined ventilation remained strong, while

longer employment duration, more smoking customers, and certain ventilation patterns (e.g., specific frequencies and 1–2 hours of ventilation time) continued to show positive associations with symptom complaints. In the fully adjusted Model 3, workers surveyed in 2018 had much lower odds of eye irritation/pain (aOR ≈ 0.22, 95% CI ≈ 0.14–0.34). Mechanical and combined ventilation were again associated with reduced odds (aOR ≈ 0.24–0.34). Longer employment duration (5–10 years vs. <1 year) and having 30–50 smoking customers per day (vs. <10) remained significant risk factors for eye symptoms. Table 3 shows the multivariable logistic regression analysis for eye irritation/pain during working hours.

Table 3. Multivariable logistic regression analysis for eye irritation/pain during working hours

Variable	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Survey year (ref.: 2017)			
2018	0.21 (0.14 – 0.32)	0.22 (0.14 – 0.33)	0.22 (0.14 – 0.34)
Ventilation type (ref.: natural only)			
Mechanical/central	0.29 (0.19 – 0.46)	0.36 (0.21 – 0.62)	0.34 (0.19 – 0.59)
Natural + Mechanical	0.20 (0.11 – 0.38)	0.27 (0.14 – 0.55)	0.24 (0.12 – 0.50)
Employment duration (ref.: < 1 year)			
5-10 years	2.62 (1.46 – 4.70)	2.74 (1.43 – 5.24)	2.58 (1.33 – 5.03)
≥ 10 years	2.02 (1.01 – 4.04)	2.27 (1.10 – 5.57)	2.24 (0.98 – 5.15)
Smoking customers/day (ref.: < 10)			
30 - 50	2.89 (1.22 – 6.80)	2.74 (1.07 – 7.04)	2.70 (1.02 – 7.10)

*Model 1: Unadjusted; Model 2: Adjusted for general characteristics; Model 3: Fully adjusted for general and work characteristics. Bold = p<0.05

Factors associated with facial flushing/ headache

For facial flushing/headache, Model 1 indicated that workers surveyed in 2018 had substantially lower odds (OR ≈ 0.17, 95% CI ≈ 0.10–0.30), and facilities with smoking rooms or mechanical/ combined ventilation had fewer complaints (OR ≈ 0.15–0.32). Higher education, working in Nowon district (vs. Seocho), longer working hours (≥15 hours per day), cooking inside the facility, more windows, and higher ventilation frequencies were positively associated with facial flushing/headache. After adjustment for general characteristics (Model 2), the 2018 survey remained protective (OR ≈ 0.18, 95% CI ≈ 0.10–0.31), and combined ventilation continued to show significantly lower odds of facial symptoms. Nowon district, higher education levels, longer employment duration, long daily working hours, and cooking inside the facility showed strong positive associations with facial flushing/headache. In the final Model 3, workers surveyed in 2018 had significantly lower odds of facial flushing/headache (aOR ≈ 0.19, 95% CI ≈ 0.11–0.34). Mechanical and combined ventilation types remained protective (aOR ≈ 0.20–0.51), while working in Nowon district, higher education, longer employment duration, and cooking inside the facility were associated with increased symptom prevalence. Table 4 shows the multivariable logistic regression analysis for facial flushing/headache during working hours.

Table 4. Multivariable logistic regression analysis for facial flushing/headache during working hours

Variable	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Survey year (ref.: 2017)			
2018	0.17 (0.10 – 0.30)	0.18 (0.10 – 0.31)	0.19 (0.11 – 0.34)
District (ref.: Seocho-gu)			
Nowon-gu	2.26 (1.35 – 3.79)	3.53 (1.87 – 6.65)	3.30 (1.69 – 6.42)
Education (ref.: ≤ High school)			
University	1.76 (1.09 – 2.86)	2.07 (1.14 – 3.77)	2.14 (1.14 – 4.01)
Graduate school	5.44 (2.01 – 14.72)	4.41 (1.38 – 14.13)	5.48 (1.17 – 14.24)
Employment duration (ref.: < 1 year)			
5-10 years	3.59 (1.88 – 6.83)	4.41 (2.07 – 9.39)	4.24 (1.97 – 9.14)
Cooking (ref.: No)			
Yes	2.61 (1.35 – 5.04)	3.38 (1.54 – 7.40)	2.35 (1.01 – 5.44)

Table 4. Continued

Variable	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Ventilation type (ref.: natural only)			
Mechanical/central	0.31 (0.1- – 0.51)	0.62 (0.35 – 1.09)	0.51 (0.26 – 0.98)
Natural + Mechanical	0.15 (0.07 – 0.34)	0.23 (0.09 – 0.55)	0.20 (0.08 – 0.51)

*Model 1: Unadjusted; Model 2: Adjusted for general characteristics; Model 3: Fully adjusted for general and work characteristics. Bold = $p<0.05$

This study examined the health impact of a smoke-free policy in billiard halls and screen golf clubs in selected districts of Seoul by analyzing workers' subjective respiratory and sensory symptoms in relation to general characteristics, work conditions, facility features, and ventilation characteristics. Overall, the implementation of the smoke-free policy was associated with reductions in multiple symptoms, and facilities with mechanical or combined ventilation systems showed consistently fewer complaints compared with those relying solely on natural ventilation. The finding that screen golf club workers experienced fewer respiratory symptoms than billiard hall workers may be explained by structural differences. Screen golf clubs are usually segmented into independent rooms, and pollutants generated in customer areas (e.g., particles from smoking or physical activity) may be less likely to disperse into the main working areas such as lobbies, reducing workers' exposure. In contrast, billiard halls tend to have open layouts without effective barriers, so that smoking or other pollutant-generating activities can directly and uniformly impact the entire space. Previous measurements showing lower PM_{10} and $PM_{2.5}$ levels in screen golf clubs than in billiard halls support this interpretation [3, 5].

The decrease in symptom complaints after the smoke-free policy is consistent with studies from Sweden, Ireland, and Scotland, where hospitality workers experienced improved respiratory and sensory symptoms following the implementation of smoke-free laws, along with reductions in exposure to carcinogenic substances such as benzene and a lowered risk of respiratory diseases such as lung cancer [9, 10, 12]. Additionally, prior research has reported that smokers tend to experience more subjective symptoms than non-smokers, and that biomarkers of secondhand smoke exposure, such as urinary cotinine, show positive correlations with symptom scores, supporting a link between secondhand smoke and symptom burden [13].

Air purifiers have been shown to reduce concentrations of particulate matter and Total Volatile Organic Compounds (TVOCs), which can mitigate inflammation of the respiratory tract and reduce the risk of asthma exacerbation and chronic obstructive pulmonary disease [9-15]. Certain VOCs, including toluene, can irritate the respiratory tract, eyes, and skin, causing symptoms such as eye irritation and headache [16, 17]. In this study, the presence of air purifiers was significantly associated with reduced cough but was less clearly related to other symptoms, suggesting that stand-alone air cleaning may not be sufficient to address the broader spectrum of

pollutants in these facilities.

Interestingly, a higher number of windows and longer ventilation times were not always protective and, in some cases, were associated with increased symptoms. This may reflect the influence of outdoor air pollution: when ambient air is heavily polluted, natural ventilation can introduce particulate matter, benzene, toluene, and nitrogen dioxide into the indoor environment, potentially aggravating respiratory and skin conditions such as atopic dermatitis. Inadequate or intermittently performed ventilation may also fail to remove indoor pollutants effectively, thus worsening indoor air quality rather than improving it [18]. Prior work has demonstrated that even with active ventilation systems, fine respirable particles and polycyclic aromatic hydrocarbons derived from secondhand smoke cannot be fully controlled without completely eliminating indoor smoking, highlighting the necessity of comprehensive smoke-free policies [12].

The findings that cooking inside the facility and having a large number of smoking customers were associated with greater symptom complaints indicate that additional pollutant sources beyond smoking need to be considered in indoor air quality management. Combustion by-products and VOCs from cooking can contribute to headaches, facial flushing, and eye irritation [19]. Moreover, the association of longer employment duration and longer working hours with higher symptom prevalence suggests cumulative exposure and potential dose–response relationships in these environments.

This study has several strengths. It is one of the few investigations in Korea to analyze the relationships between smoke-free policy implementation, facility and ventilation characteristics, and workers' subjective symptoms in small indoor sports facilities. The inclusion of both billiard halls and screen golf clubs allows comparison between different types of sports facilities with distinct structural and usage patterns. Furthermore, the use of multivariable logistic regression with stepwise adjustment provides insights into the independent effects of key job environment factors. However, several limitations should be acknowledged. First, the study was conducted only in three districts of Seoul, which may limit the generalizability of the findings to other regions such as Gyeonggi and Incheon. Additional studies in diverse geographic areas and facility types are needed. Second, health outcomes were assessed using self-reported questionnaires rather than clinical examinations, making the results susceptible to recall bias and subjective perception. Third, although previous studies and existing measurements informed the selection of indoor air–related job environment variables, detailed concurrent measurements of specific indoor pollutants (e.g., $PM_{2.5}$, nicotine, VOCs) were limited, constraining more precise exposure–response analyses. Fourth, the cross-sectional design captures associations between job environment factors and symptoms but cannot definitively establish causality. Fifth, ventilation characteristics and the presence of air purifiers were assessed using self-reported questionnaire data only, and no systematic objective confirmation through site inspection or direct measurement was conducted. Accordingly, these variables may be subject to reporting bias and misclassification, which should be considered when interpreting the findings. Sixth, because facility identifiers were not available, we were unable to account for intra-facility correlation in the statistical models. Therefore, the analyses assumed independence among workers, and the standard errors and confidence intervals may be underestimated. This should be considered when interpreting the findings. Additional effect modification analyses by ventilation type, facility type, and cooking were not performed in this study, and this should be considered a limitation. Finally, lifestyle factors that may influence

health outcomes, such as alcohol consumption and physical activity, were not fully captured in this analysis. This study consisted of two cross-sectional surveys conducted before and after policy implementation. Therefore, the data do not represent a longitudinal cohort, and the observed differences should be interpreted as associations rather than causal effects. Although the observed reduction in symptom prevalence after 2018 is consistent with the introduction of the smoke-free policy, these findings should be interpreted as associations rather than causal effects. The magnitude of change may also have been influenced by policy enforcement and compliance levels, variation in workplace implementation, ambient air pollution, and other time-varying contextual factors such as economic or operational changes in the facilities. Because these factors were not directly measured, they may have contributed to the observed differences between survey years. The present study did not directly measure enforcement intensity, compliance with smoke-free regulations, or outdoor air pollution levels. Therefore, the observed between-year differences cannot be attributed solely to the policy itself. These limitations should be considered when interpreting the general health impact of the smoke-free policy on facility workers. Despite these limitations, this study provides valuable evidence on the health benefits of smoke-free policies in understudied small indoor sports facilities and underscores the critical role of ventilation systems in protecting workers from indoor air pollutants, offering actionable insights for occupational health policy and facility management in similar settings.

Conclusion

This study suggests that smoke-free policy implementation, together with appropriate ventilation management and control of additional indoor pollutant sources, may contribute to healthier working environments in small indoor sports facilities. The findings highlight the need for integrated indoor air quality management that considers facility design, ventilation practices, and non-tobacco emission sources such as cooking. Future studies should incorporate objective exposure measurements, detailed assessment of policy enforcement and compliance, and longitudinal designs to better clarify causal pathways and support targeted occupational health interventions.

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Competing interests

The authors declare no conflicts of interest

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Ethical considerations

No experiments on humans or animals were performed in this study, and no clinical or identifiable personal data were collected. This research consisted of an anonymous, non interventional questionnaire survey of adult workers. According to the Bioethics and Safety Act of the Republic of Korea, such minimal risk survey research is exempt from institutional review board approval; therefore, separate ethical approval and written informed consent were not required for this study.

Ethical issues (Including plagiarism, Informed

Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors

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