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Effect of a Smoking Ban on Respiratory Health in Nonsmoking Hospitality Workers

A Prospective Cohort Study

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Objective: The aim of this study was to examine the effect of a smoking ban on lung function, fractional exhaled nitric oxide, and respiratory symptoms in nonsmoking hospitality workers. **Methods:** Secondhand smoke exposure at the workplace, spirometry, and fractional exhaled nitric oxide were measured in 92 nonsmoking hospitality workers before as well as twice after a smoking ban. **Results:** At baseline, secondhand smoke-exposed hospitality workers had lung function values significantly below the population average. After the smoking ban, the covariate-adjusted odds ratio for cough was 0.59 (95% confidence interval, 0.36 to 0.93) and for chronic bronchitis 0.75 (95% confidence interval, 0.55 to 1.02) compared with the preban period. **Conclusions:** The below-average lung function before the smoking ban indicates chronic damages from long-term exposure. Respiratory symptoms such as cough decreased within 12 months after the ban.

It has been established that both active and passive smoking are closely linked to progressive lung function decline.[1,2] Cross-sectional studies have observed significantly higher prevalences for respiratory symptoms such as cold, cough, phlegm, and throat problems in persons exposed to secondhand smoke (SHS) at the workplace.[3–6] In the last decades, smoking bans for public places including hospitality venues were implemented in many countries all over the world, and potential benefits on respiratory health were evaluated. Several longitudinal studies examined self-reported respiratory symptoms and lung function before and after a smoking ban. Some researchers found less respiratory symptoms in both nonsmokers and smokers[7,8] and could show that this reduction did not occur in the control group.[8,9] Although respiratory symptoms are very consistently reported as declining,[7,8,10,11] findings on lung function outcomes are more variable. Two studies in bar workers reported significant improvements in forced vital capacity (FVC), but not in forced expiratory volume in 1 second (FEV_1) or forced expiratory flow between 25% to 75% ($FEF_{25\%–75\%}$) after 2 months[10] or 1 year[12] of smoking ban introduction. A study from the French part of Switzerland also observed significant improvements in FVC, most pronounced in women, nonsmokers, and persons above 35 years.[13] Conversely, another study found a significant increase in FEV_1 in healthy and asthmatic bar workers within 1 month after ban implementation but did not report any findings on FVC or $FEF_{25\%–75\%}$.[11] A Swedish study did not observe any noteworthy improvements in lung function parameters after the smoking ban.[14] A recent Swiss study reported a significant decrease in hospital admission for acute exacerbation of chronic obstructive pulmonary disease after a smoking ban but no changes for asthma or pneumonia.[15]

Fractional exhaled nitric oxide (FeNO) is a marker of airway inflammation that has been increasingly studied in the past 20 years.[16] Measurement of FeNO is noninvasive and highly reproducible and can easily be performed on-line or off-line.[17] It has primarily been used to investigate and monitor asthma. Allergen exposure upregulates inducible NO synthase in the airway epithelial cells.[16] Cigarette smoke is believed to downregulate inducible NO synthase via a potential negative feedback mechanism.[18] Decreased FeNO levels have been observed in smoking asthma groups[19] as well as in nonatopic smokers[20] and rise after smoking cessation.[21] The same mechanisms might reduce FeNO levels when being exposed to SHS. Nevertheless, empirical data are scarce and ambiguous. Although one study found decreased FeNO levels in nonsmokers exposed to SHS,[22] several studies reported the opposite in young children exposed to parental smoking.[23,24] This is the first study to look at the effects of SHS exposure elimination at the workplace on FeNO levels in nonsmokers.

The implementation of a national smoking ban in Switzerland in May 2010 was used to set up a prospective, longitudinal study of nonsmoking hospitality workers in three cantons: Zurich, Basel City, and Basel County. The two aims of the study were (1) to compare baseline spirometry values of SHS-exposed hospitality workers with reference values from the literature and (2) to directly relate workplace SHS exposure in nonsmoking hospitality workers before and 6 to 12 months after a smoking ban to their respiratory health.

METHODS

Study Population

The study population consisted of 92 participants in total: 62 nonsmoking hospitality workers who had worked for at least 1 year in venues where smoking was either partially or completely allowed before the introduction of the smoking ban, 14 nonsmoking hospitality workers who worked in a smoke-free environment at baseline, and 16 nonsmokers who were regularly exposed to SHS without being employed in the hospitality sector. These additional 16 nonsmokers were recruited to enlarge the sample size. All hospitality workers worked in a hospitality venue in one of the study cantons. Data were collected between March 2010 and December 2011.

To recruit hospitality workers, a list of hospitality venues in the cantons of Zurich, Basel City, and Basel County was created using the digital Swiss phonebook from 2009. Each venue received a letter containing information about the study, with a request to distribute screening questionnaires to staff serving at tables or at the bar (waiting staff) and for air measurements to be performed by the

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study team. These letters were followed by phone calls and visits 2 weeks later.

Screening questionnaires were distributed to the waiting staff, to provide information on the eligibility criteria, which were being between 18 and 65 years of age, working at least half-time, having worked for at least 1 year in the hospitality sector, and having been a nonsmoker for at least 5 years. Eligible study participants were invited to a health examination, which was carried out in one of the two study centers in Basel City and Zurich.

The nonhospitality workers were recruited by means of an online advertisement looking for nonsmokers who were exposed to SHS on a regular basis, either privately or at work.

Health Examinations

Ethical approval was obtained from the EKBB (ethics committee of both cantons of Basel), and all participants signed an informed consent form before every examination (Ref. No. EK 317/09).

A baseline examination was conducted within the 3 months before the introduction of the smoking ban. Subsequently, all study participants who were exposed to SHS at baseline were invited for two follow-up examinations at 3 to 6 months and 9 to 12 months after the smoking ban introduction.

The health examinations comprised cardiovascular and respiratory tests. Spirometry tests were performed using a portable Easy-One spirometer from ndd Medical Technologies (Andover, MA) and read out with the EasyWare software. Each participant had to wear a nose clip and was required to perform three successful measurements within a maximum of eight trials according to the American Thoracic Society guidelines.[25] For FVC and FEV_1, the single highest value of all tests was used for analysis; for $FEF_{25\%–75\%}$ and the FEV_1/FVC ratio, the value from the best test (FVC + FEV_1 = maximum) was taken.

Fractional exhaled nitric oxide measurements were performed with a pressure-controlled SIEVERS NOA 280 off-line kit (GE Power&Water, Boulder, CO) using a Mylar bag (FMI GmbH, Seeheim, Germany) to collect the exhaled breath following the American Thoracic Society/European Respiratory Society recommendations.[26] Participants were asked to inhale through a mouthpiece attached to an NO-scrubber and then exhale against a set expiratory resistance maintaining a constant pressure of 12 to 16 mbar without wearing a mouthpiece. The constant pressure was achieved by visual feedback from an inline pressure gauge. The pressure range allowed maintaining a constant expiratory flow of 50 mL/s. After 5 seconds, the expiratory air was collected into a Mylar bag® until the bag was full. Ambient air was pumped into an additional bag to check for exceeding levels of ambient FeNO. The FeNO content was measured within 12 hours with an EcoMedics CLD 88 analyzer (EcoMedics, Duernten, Switzerland) using Spiroware 30.0 (ndd Medical Technologies, Andover, MA). For data analysis the average of the two personal measurements was used.

Participants were defined as asthma groups if they reported having suffered from asthma at an adult age. Asthma groups currently on inhaled corticosteroids were excluded from the analysis as inhaled corticosteroids decrease FeNO levels (four baseline and six follow-up observations). A skin prick test at baseline comparing the six most common allergens—birch, mixed grasses, alternaria, mugwort, cat hair, and dermatophagoides—with a positive and a negative control was performed in each participant at baseline. Test solutions were obtained from Trimedal in Dietlikon, Switzerland. Participants were considered sensitized if they showed a minimal wheal size of 3 mm to at least one tested allergen.

Interviews

Respiratory and allergy symptoms were assessed during the health examinations in a computer-based interview adapted from a standardized questionnaire previously evaluated in the Swiss population.[27] We asked about respiratory and allergy symptoms in the last 3 to 12 months. Asthmatic symptoms were defined as breathlessness, wheezing, or chest tightness. A person was considered to have chronic bronchitis if he or she stated to suffer from cough or phlegm.[27] Participants were counted as positive for hay fever if they had suffered from symptoms in the present or previous years. Rhinitis was defined as sneezing and a running nose during the past 12 months without having a cold or influenza. Eczema was considered to be present if participants had ever had an itchy skin rash in areas typical for eczema.

Exposure Measurements

Secondhand smoke was objectively measured using newly developed Monitor of Nicotine (MoNIC) passive sampling badges as previously described.[28] MoNIC badges are glass fiber filters that are washed with distilled water, methanol, and CH_2Cl_2, impregnated with 5-mg sodium bisulphate per filter, and placed in an airtight plastic case. Badges were always transported between study centers, participants, and the laboratory in these airtight cases. The amount of nicotine on the badge was determined by gas chromatography and used to calculate the number of passively cigarette equivalents per day (CE/d) assuming a nicotine content of 0.2 mg per cigarette and an average ventilation rate of 10 L/min.[13,29]

In the hospitality venues that agreed to participate, at least one MoNIC badge was placed for 1 week, near the bar where waiting personnel spend much of their working time (hereafter referred to as "workplace badge"). We calculated a time-weighted average workplace exposure[28] for each hospitality worker by multiplying their average workplace concentration by their workload (in percentage of full-time equivalent) and by 0.6, which represents time present at the workplace, includes holidays and considers the fact that nicotine levels decrease when a venue is unattended.[28] For nonhospitality workers, average SHS exposure was obtained from a personal badge that participants wore on themselves on a typical day.

Data Analysis

To estimate the long-term consequences of working in SHS-exposed hospitality venues on lung function, we calculated for each study participant, who was exposed to SHS at baseline, age, sex, and height-adjusted percentage FEV_1, and FVC values from reference values for a nonsmoking Swiss population sample.[30]

By considering the within-subject correlation, mixed linear random-intercept regression models were used to relate respiratory parameters to workplace SHS exposure at the time of each health examination (baseline and follow-ups). Lung function models were calculated adjusting for age, sex, height, body mass index (linear), asthma (binary), season (cosine function), and device number (categorical). FeNO levels were log-transformed and back-transformed model coefficients are reported. FeNO models were adjusted for age, sex, allergy (binary), season (cosine function), and time of day (cosine function). The cosine function for time of day variations assigned the value of 0 to 12 PM and 1 to 12 AM and for seasonal variations the value of 0 to July 1 and 1 to January 1. Respiratory symptoms were evaluated by means of generalized estimating equation regression models adjusted for age, sex, season, and systolic blood pressure.

Data were analyzed using Stata 10.1 and Stata 12.0 (StataCorp LP, College Station, TX).

RESULTS

This study sample comprised 92 participants (Table 1) with no one suffering from chronic obstructive pulmonary disease. Thereof 23 individuals were exposed throughout the study, 55 were only exposed at baseline, but not anymore at follow-up and 14 were never exposed. At baseline average exposure of the 14 study participants

TABLE 1. Characteristics of the Study Population ($n = 92$)

Variables	Values*
Female sex, *n* (%)	57 (62)
Age, yrs, *n* (95% CI)	40.3 (37.6–43.0)
BMI, kg/m^2, *n* (95% CI)	25.6 (24.7–26.5)
Smoking status, *n* (%)	
Never-smokers	67 (72.8)
Ex-smokers	25 (27.2)
Self-reported physical activity,† *n* (%)	45 (48.9)
Respiratory symptoms, *n* (%)	
Bronchitis symptoms	
Cough	27 (29.4)
Phlegm	11 (12.0)
Chronic bronchitis	2 (2.2)
Asthma symptoms	24 (26.1)
Allergy symptoms, *n* (%)	
Hay fever	21 (22.8)
Rhinitis	30 (32.6)
Eczema	6 (6.5)
Comorbidities, *n* (%)	
Self-reported bronchial asthma	13 (14.1)
Allergic‡	60 (65.2)
Workplace and exposure, *n* = 76	
Average workload, % (95% CI)	92.6 (88.8–96.4)
Type of workplace, *n* (%)	
Bar	7 (9.2)
Café	18 (23.7)
Restaurant	51 (67.1)
Exposed throughout the study, *n* (%)	23 (25.0)
Exposed at baseline, not exposed anymore at follow-up, *n* (%)	55 (59.8)
Never exposed, *n* (%)	14 (15.2)

*Values shown are arithmetic means at baseline except where indicated.
†Defined as answered yes to "Do you sweat at least once/week due to physical activity?"
‡Reacted positively to at least one skin prick test.
BMI, body mass index; CI, confidence interval.

who were never exposed to SHS was 0.1 (95% confidence interval [CI], 0.0 to 0.2) CE/d, whereas exposure in the 78 SHS-exposed study participants was 2.4 (95% CI, 1.7 to 3.1) CE/d. Of these 78 participants, 55 were not anymore exposed at follow-up and their SHS exposure decreased from 2.6 (95% CI: 1.7 to 3.4) CE/d to 0.2 (95% CI: 0.1 to 0.2) CE/d while staying at 1.6 (95% CI, 0.7 to 2.5) CE/d for the 23 participants who were still exposed at the follow-up examinations.

From the lung function analyses, 20 observations were excluded because of insufficient quality ($n = 16$), technical problems ($n = 1$), or insufficient cooperation ($n = 3$). For FeNO, 10 baseline and one follow-up measurements had to be excluded from the analysis because of technical problems.

At baseline, age, sex, and height-specific fitted FVC and FEV_1 curves of our sample of nonsmoking SHS-exposed hospitality workers were below the population reference curve[30] for most of the age range in men and women (Fig. 1). The difference was most pronounced for FEV_1 in women (Table 2). Nevertheless, longitudinal exposure-response models did not indicate an association between lung function parameters and SHS exposure (Table 3). Forced vital capacity showed a decreasing tendency with increasing exposure, but this association was not significant. When using exposure measures from personal badges that took into account private exposure, no association could be observed either (data not shown).

Average FeNO levels of nonasthmatic study participants were 11.3 (95% CI, 10.3 to 12.5) ppb and of asthmatic study participants were 14.3 (95% CI, 8.6 to 20.0) ppb. Fractional exhaled nitric oxide was not related to SHS exposure in the longitudinal exposure-response model (Table 3). Other covariables that were included into the model such as smoking history, former smoking status, physical activity, or childhood SHS exposure did not show any association either and were therefore excluded from the final models. Nevertheless, FeNO values were 36.1% (95% CI, 6.9 to 73.2) higher on January 1 compared with July 1 ($P = 0.01$) according to the cosine seasonality function in the model.

The exposure-response model yielded an odds ratio of 1.25 (95% CI, 1.03 to 1.53) per CE/d increase in SHS exposure for cough and 1.13 (95% CI, 0.99 to 1.28) for chronic bronchitis (Table 4). Because the average SHS exposure reduction from the smoking ban was 2.4 CE/d, these odds ratios translate in a smoking ban odds ratio of 0.59 (95% CI, 0.36 to 0.93) for cough and 0.75 (95% CI, 0.55 to 1.02) for chronic bronchitis. We found no clear associations for phlegm and asthma symptoms.

DISCUSSION

In this study population, of SHS-exposed nonsmoking hospitality workers, we observed significantly below-average values of FVC and FEV_1 before implementation of a smoking ban. We found indications that introducing a smoke-free workplace reduced cough and chronic bronchitis but not lung function parameters or FeNO.

In line with other smoking ban studies in hospitality workers,[10–12] below-average lung function was observed in the study participants who were exposed to SHS at baseline and had worked under such circumstances for at least 1 year but mostly substantially longer. On average our participants had worked in an-SHS exposed environment for 8.5 years, ranging from 1 to 33 years. In women the reduction of the lung function compared with the reference curve increased with age. For men, this pattern was impeded by one observation with exceptionally good lung function at high age. This pattern, although on the basis of few observations, suggests a continuous degradation of the lung function with increasing exposure time. In contrast to our hypothesis that lung function would increase during the study, we did not observe any improvement in lung function 6 to 12 months after the introduction of the smoke-free workplaces. This corresponds to the findings of a Swedish study looking at 71 smokers and nonsmokers that did not find any significant changes in spirometry 1 year after implementation of a smoking ban[14] but contradicts three other studies that observed significant improvements in FVC of bar workers after 8 weeks[10] to 1 year.[12, 13] According to our exposure-response model, FVC decreased by 0.16 L per daily cigarette equivalent increase in SHS exposure, which was not statistically significant ($P = 0.26$) (Table 3).

This nonsignificance could be explained by the relatively small exposure reduction of 2.40 CE/d on average from before to after the ban. Low exposure levels may be explained by the fact that most of this study subjects worked in restaurants that served food. Our measurements performed in bars yielded much higher SHS levels, but waiters were mostly active smokers and/or unwilling to participate in the study. All previous studies reporting significant improvements in FVC or FEV_1 looked at bar workers who presumably experienced a sharper decline in exposure.[10–12]

To the best of our knowledge, this is the first study to prospectively measure the effect of a smoking ban on FeNO. We hypothesized that the introduction of smoke-free workplaces would lead to an increase in FeNO as has been observed in a smoking cessation study,[21] but we did not observe an association between SHS exposure and FeNO levels in the exposure-response analysis. Different developments in heavily and lightly SHS-exposed persons regarding FeNO,

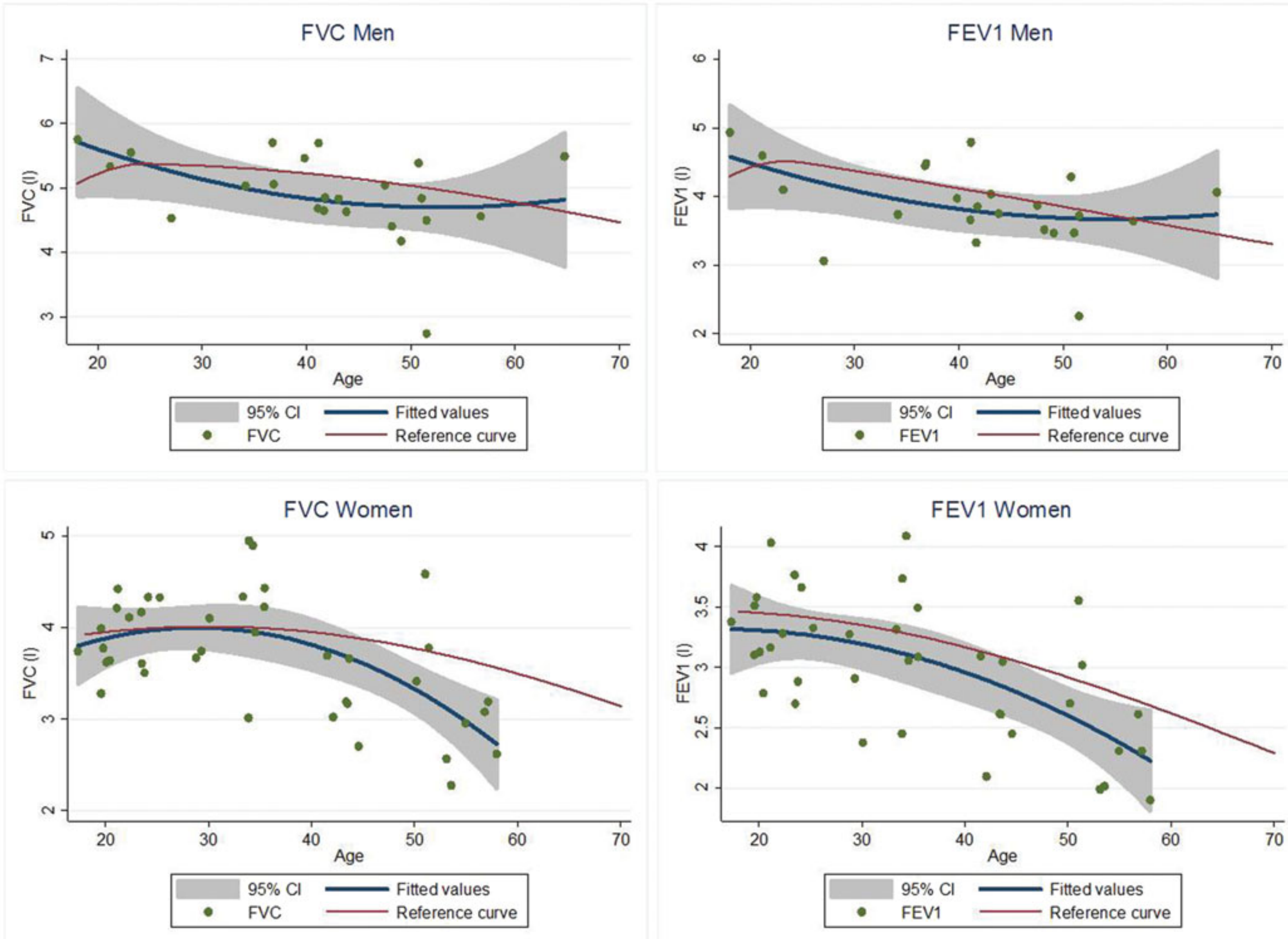

FIGURE 1. Fitted FVC and FEV_1 at baseline for men ($n = 23$) and women ($n = 39$) adjusted for age and height in comparison to reference curves.

TABLE 2. FVC and FEV_1 Baseline Measurements of Exposed Participants in Comparison to Reference Values[29]

	All ($n = 62$)	Women ($n = 39$)	Men ($n = 23$)
FVC (% of reference value)	93.1 (90.2–95.9)	93.3 (89.7–97.0)	92.6 (87.8–97.5)
FEV_1 (% of reference value)	92.4 (89.4–95.4)	91.9 (88.2–95.6)	93.2 (87.7–98.6)

FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity.

as proposed by Malinovschi et al[31] for heavy and light smokers, could explain this. The interacting effect of SHS[32] and asthma[33,34] on FeNO levels is complex and not yet fully understood. In addition to allergic inflammation, further mechanisms may be involved in FeNO synthesis as indicated by the higher fluctuation observed in asthmatic groups in this study. So far only 11% to 30% of the variance of FeNO levels is explained by anthropometric characteristics compared with spirometry where 60% to 75% of the variation is explained.[16] This is mainly because measurement techniques and the selected influencing factors differ between studies.

Research on the effect of active smoking on FeNO is fairly consistent with smokers showing reduced levels.[17,21,22] Interestingly, our observed FeNO values were also at the lower end or even below the range of population-based reference FeNO values that have been published[35,36] although these cover a fairly wide range. Dressel et al[35] measured values with a geometric mean of 19.6 ± 1.92 ppb in a sample of 897 women with an average age of 34.5 ± 13 years and a 24.3% smoking prevalence. Matsunaga et al[36] reports mean values of 16.9 (95% CI, 6.5 to 35.0) ppb for a nonsmoking Japanese adult population of 240. Our observed low levels may be the consequence of long-term SHS exposure similar to the reduced FeNO levels of smokers.

We also measured heart rate variability and pulse wave velocity in the same study and reported these findings elsewhere.[37] We found significant improvements in these cardiovascular parameters after the smoking ban introduction. This suggests that cardiovascular indicators react more sensitively within the first 12 months after a substantial SHS exposure reduction than respiratory markers.

A major asset of this study is the prospective design with repeated health examinations. The prospective design avoids recall

TABLE 3. Multivariable Exposure-Response Models Relating SHS Exposure at the Workplace to Respiratory Outcomes*

	Coefficient—Change/Unit Increase in Cigarette Equivalents (95% CI)	*P* Value
FEV_1, L/s†	0.04 (−0.28 to 0.37)	0.79
FVC, L†	− 0.16 (−0.64 to 0.11)	0.26
$FEF_{25\%–75\%}$, L/s†	0.31 (−0.62 to 1.25)	0.51
FEV_1/FVC ratio†	0.16 (−0.09 to 0.41)	0.20
FeNO, ppb‡	0.8 (−2.2 to 3.9)	0.62

*From the lung function analyses, 20 observations were excluded because of insufficient quality ($n = 16$), technical problems ($n = 1$), or insufficient cooperation ($n = 3$). For FeNO, 11 measurements had to be excluded from the analysis because of technical problems.

†Adjusted for age, sex, height, BMI, asthma, season, and device.

‡Adjusted for age, sex, allergy, seasonality, and time of day.

BMI, body mass index; FEF, forced expiratory flow; FeNO, fractional exhaled nitric oxide; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; SHS, secondhand smoke.

TABLE 4. Multivariable Logistic Regression Models Relating SHS Exposure at the Workplace to Self-Reported Respiratory Symptoms*

	OR† (95% CI)	*P* Value
Cough	1.25 (1.03–1.53)	0.03
Phlegm	0.98 (0.89–1.09)	0.76
Chronic bronchitis	1.13 (0.99 to 1.28)	0.07
Asthma symptoms	1.11 (0.96 to 1.29)	0.16

*Adjusted for age, sex, season, and systolic blood pressure.

†Per unit increase in cigarette equivalents.

CI, confidence interval; OR, odds ratio; SHS, secondhand smoke.

bias in directly measured parameters—limiting this potential bias to self-reported respiratory symptoms. A further strength is that exposure data were collected at the same time as the health outcomes. By using the MoNIC badge, nicotine exposure was directly quantified without using a surrogate measure such as airborne particulate matter. A limitation of the study is the small sample size. It was particularly difficult to find SHS-exposed non-smoking hospitality workers, and we were therefore forced to include some nonhospitality workers. Potential bias from this recruitment strategy was minimized by carefully checking all relevant confounding factors in the data analysis.

CONCLUSIONS

In this study sample, of nonsmoking hospitality workers, lung function was below the average population before implementation of the smoking ban and did not change within 1 year in relation to a smoking ban implementation. Nevertheless, we found indications that cough and chronic bronchitis occurred less frequently after the smoking ban. These results indicate that damages from SHS to the respiratory system recover very slowly if at all and emphasize the need for a comprehensive smoking ban to avoid reduced lung function in nonsmokers because of SHS at the workplace.

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