

Respiratory Symptoms, Pulmonary Function, and Markers of Inflammation Among Bar Workers Before and After a Legislative Ban on Smoking in Public Places

Daniel Menzies, MBChB

Arun Nair, MBBS

Peter A. Williamson, MBChB

Stuart Schembri, MD

Mudher Z. H. Al-Khairalla, MBChB

Martyn Barnes, MBBS

Tom C. Fardon, MBChB

Lesley McFarlane, BSc

Gareth J. Magee, MSc

Brian J. Lipworth, MD

PASSIVE SMOKING IS A MAJOR worldwide public health issue. The effects on individuals exposed to secondhand smoke are difficult to quantify, but a number of studies have now established an increased risk of coronary artery disease, cerebrovascular disease, and lung cancer, and the 2006 report by the US surgeon general highlighted the causal relationship between secondhand smoke and premature death.¹⁻⁶ In addition, for patients with preexisting respiratory conditions such as asthma, secondhand smoke leads to poorer disease control and more frequent hospital admission.⁷ Recent reports have also suggested that secondhand smoke can cause impaired glucose tolerance and impaired lung development of children whose mothers are exposed while pregnant and that occupational exposure to secondhand smoke

For editorial comment see p 1778.

Context Scotland prohibited smoking in confined public places on March 26, 2006.

Objective To investigate the association of smoke-free legislation with symptoms, pulmonary function, and markers of inflammation of bar workers.

Design, Setting, and Participants This prospective observational study was conducted in Tayside, Scotland from February-June 2006. One hundred five nonasthmatic and asthmatic nonsmoking bar workers were initially enrolled, of whom 77 completed the study per protocol.

Main Outcome Measures Respiratory and sensory symptoms, spirometry measurements, serum cotinine levels, peripheral inflammatory cell count, asthma quality-of-life scores, and exhaled nitric oxide levels were evaluated before and after introduction of the smoking ban.

Results For the per-protocol analysis, the percentage of bar workers with respiratory and sensory symptoms decreased from 79.2% (n=61) before the smoke-free policy to 53.2% (n=41) (total change, -26%; 95% confidence interval [CI], -13.8% to -38.1%; $P<.001$) and 46.8% (n=38) (-32.5%; 95% CI, -19.8% to -45.2%; $P<.001$) 1 and 2 months afterward. Forced expiratory volume in the first second increased from 96.6% predicted to 104.8% (change, 8.2%; 95% CI, 3.9% to 12.4%; $P<.001$) and then 101.7% (change, 5.1%; 95% CI, 2.1% to 8.0%; $P=.002$), and serum cotinine levels decreased from 5.15 ng/mL to 3.22 ng/mL (change, -1.93 ng/mL; 95% CI, -2.83 to -1.03 ng/mL; $P<.001$) and then 2.93 ng/mL (-2.22 ng/mL; 95% CI, -3.10 to -1.34 ng/mL; $P<.001$). The total white blood cell and neutrophil count was reduced from 7610 to 6980 cells/ μ L at 2 months (-630 cells/ μ L; 95% CI, -1010 to -260 cells/ μ L; $P=.002$) and from 4440 to 4030 cells/ μ L (-410 cells/ μ L; 95% CI, -740 to -90 cells/ μ L; $P=.03$), respectively. Asthmatic bar workers also had less airway inflammation, with a reduction in exhaled nitric oxide from 34.3 parts per billion (ppb) to 27.4 ppb 1 month after the ban (0.8-fold change; 95% CI, 0.67 to 0.96 ppb; $P=.04$), and Juniper quality-of-life scores increased from 80.2 to 87.5 points (7.3 points; 95% CI, 0.1 to 14.6 points; $P=.049$).

Conclusions Smoke-free legislation was associated with significant early improvements in symptoms, spirometry measurements, and systemic inflammation of bar workers. Asthmatic bar workers also had reduced airway inflammation and improved quality of life.

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increases the likelihood of having respiratory symptoms and asthma.⁸⁻¹⁰

As the harmful effects of secondhand smoke become more widely appreciated, a number of countries have attempted to limit the health risks to the population at large by prohibiting

Author Affiliations: Asthma & Allergy Research Group, Departments of Medicine and Therapeutics (Drs Menzies, Nair, Barnes, and Lipworth, Ms McFarlane, and Mr Magee) and Respiratory Medicine (Drs Williamson, Schembri, Al-Khairalla, and Fardon), Ninewells Hospital and Medical School, Dundee, Scotland.

Corresponding Author: Daniel Menzies, MBChB, Asthma & Allergy Research Group, Ninewells Hospital and Medical School, Dundee, Scotland DD1 9SY (d.menzies@dundee.ac.uk).

smoking in public. On March 26, 2006, Scotland introduced a legislative ban on smoking in enclosed public places. One group of people most likely to benefit from this legislation is bar workers, who are exposed to high levels of second-hand smoke as part of their occupation. Indeed, recent studies involving bar workers, which were undertaken in the United States and Ireland when similar bans were implemented, demonstrated improvements in respiratory symptoms attributable to second-hand smoke and also slightly improved pulmonary function.¹¹⁻¹³ Tobacco smoke is known to mediate many of its harmful effects by promoting vascular and pulmonary inflammation, and these effects have also been observed in people exposed to secondhand smoke, as well as active smokers.^{14,15}

We conducted a prospective observational study into the effect of the recently introduced smoke-free legislation on bar workers' health in Scotland. In addition to quantifying spirometric indices and symptoms attributable to secondhand smoke exposure, we have also examined markers of airway and systemic inflammation and, in a subgroup of asthmatic bar workers, the impact on quality of life and airway hyperreactivity.

METHODS

The study took place in Dundee and Perth, in the east of Scotland, between February and June 2006. The Tayside Committee for Medical Research Ethics reviewed and formally approved the study before the trial began, and all participants gave written informed consent before inclusion. All participants were reimbursed £10 (approximately US \$18) for each visit.

Participant Recruitment and Selection

Bar owners in Dundee and Perth were sequentially identified from the telephone directory and their staff invited to participate. Individuals expressing an interest were supplied with written information about the study and then visited shortly afterward by an investiga-

tor to collect names and contact details. To be eligible for inclusion, bar staff had to be nonsmokers (ex-smokers were permitted), without a history of significant respiratory disease except asthma or rhinitis, who anticipated working in the bar until completion of the study (therefore excluding temporary staff). Any participants identified as asthmatic were invited to take part in an additional subgroup study.

Study Visits

Participants were interviewed at their place of work during a usual shift by an investigator 1 month before and then 1 and 2 months after implementation of the smoke-free legislation. Asthmatic participants involved in the subgroup study attended the research department 1 month before and 2 months after the introduction of the legislation, in addition to their workplace visits.

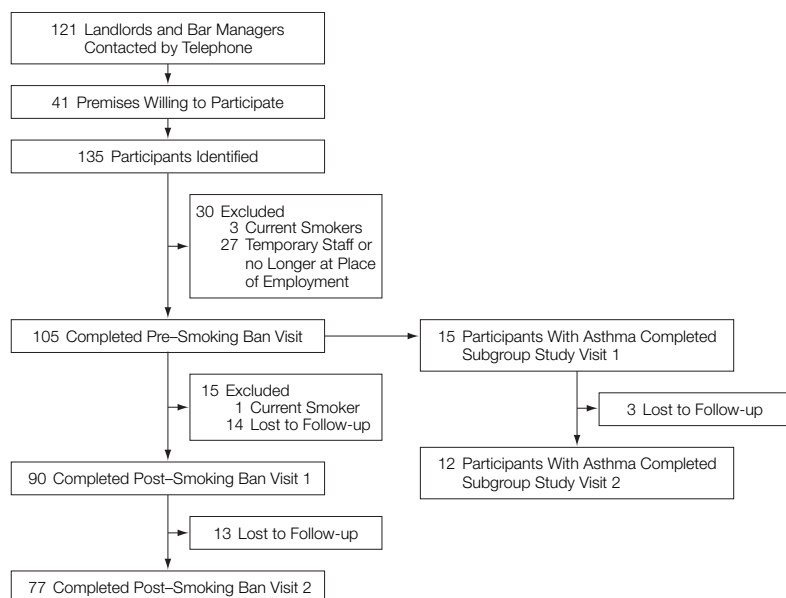
At each workplace visit, data on hours worked that week, smoking status (including current cohabitation with a smoker), and self-reported estimation of total smoke exposure (workplace and home) in the preceding week were gathered, and an abbreviated International Union Against Tuberculosis and Lung Disease respiratory questionnaire was completed. This questionnaire, which has been successfully used in similar studies, asks participants to report the presence or absence of symptoms in 2 domains (respiratory and sensory) in the preceding 1 month.^{11,12} The respiratory symptoms are wheeze, shortness of breath, cough, and phlegm, and the sensory symptoms are red or irritated eyes, painful throat and nasal itch, runny nose, and sneeze. In addition, the following measurements were made: spirometry with a portable handheld spirometer (Piko-1; Ferraris Respiratory, Louisville, Colo) to determine forced expiratory volume in the first second (FEV₁), with the best value of 3 technically acceptable maneuvers recorded and expressed as predicted values^{16,17}; quantification of exhaled nitric oxide (FE_{NO}) with a portable nitric oxide analyzer (MINO; Aerocrine AB,

Solna, Stockholm, Sweden)^{18,19}; and measurement of peripheral blood white cell and neutrophil count, serum cotinine levels (Serex Inc, Maywood, NJ), and C-reactive protein (Kalon Biological Ltd, Guildford, Surrey, England).

The asthmatic participants involved in the subgroup study had the following additional measurements made at each visit: bronchial challenge to determine the provocative concentration of methacholine causing a 10% decrease in FEV₁ (PC₁₀),^{20,21} quantification of fractional alveolar nitric oxide concentration to evaluate small-airway inflammation (Niox chemiluminescence analyzer; Aerocrine AB),^{18,22} and self-administration of the Juniper Mini Asthma Quality of Life Questionnaire.²³ In addition, data on current prescribed asthma medication were gathered.

Statistical Analysis

A priori calculations revealed that a minimum of 74 patients completing the study was required to give 80% power (α error = .05 2-tailed) to demonstrate a 35% reduction in the percentage of participants experiencing any symptom after the introduction of the smoke-free policy. In addition, 12 patients were required to complete the asthmatic subgroup study to detect a 1 doubling-dilution shift in methacholine hyperresponsiveness, with 80% power and an α error of .05.²⁴ As such, we intended to recruit 105 participants into the study and 16 participants into the subgroup to allow for a 30% dropout rate. Distribution plots were carried out on all data to assess for normality, and any non-Gaussian data were evaluated with either Wilcoxon signed rank test or, where appropriate, data logarithmically transformed before analysis. Comparisons of continuous data were made by an overall analysis of variance, followed by Bonferroni corrected, multiple-range testing, to obviate multiple pairwise comparisons, with the overall α error set at .05 (2-tailed). The percentage of participants reporting symptoms was compared with the McNemar χ^2 test. Analysis was carried

Figure. Participant Recruitment, Flow, and Dropouts

The mean (SD) timing of visits with regard to implementation of the smoking ban was 32.4 (7.7) days for preban, 32.9 (5.5) days for postban visit 1, 70.2 (5.7) days for postban visit 2, 20.8 (13.2) days for the preban asthma subgroup visit, and 73.8 (4.2) days for the postban asthma subgroup visit. All participants were questioned about personal smoking habits at each visit. Before the first visits, 3 participants admitted to active smoking and were excluded. Between the preban and postban visit 1, 1 participant began smoking and was excluded from the rest of the trial (not included in the final analysis).

Table 1. Participant Demographics (N=77)

	Value
Age, mean (SD), y	37.5 (13.7)
Male, No. (%)	41 (53)
Working in bars, mean (SD), y	9.5 (10.1)
Smoking history	
Ex-smoker, No. (%)	29 (37.7)
Years stopped, mean (SD)	10.2 (10.8)
Pack-years, mean (SD)	16.1 (24.8)
Currently living with smoker, No. (%)	17 (22.1)
Concomitant respiratory disease, No. (%)	
Asthma	11 (14.3)
Rhinitis	4 (5.2)
Both	8 (10.4)

out per protocol, so only participants who completed all scheduled visits were included in the final calculations. Analyses were conducted with SPSS v. 13 software (SPSS Inc, Chicago, Ill).

RESULTS

A total of 135 potential volunteers in 41 bars initially expressed an interest in participating in the study. Before the trial, 3 participants were excluded because they were current smokers, and a further 27 were unsuitable because

either they were temporary staff and therefore unable to complete the trial per protocol or had already left their place of employment by the first preban visit. Of the 105 participants enrolled, 1 participant began smoking and was excluded, and 27 were lost to follow-up during the study (FIGURE). Fifteen individuals with asthma agreed to take part in the subgroup study, and 12 completed both visits. Participant demographics are detailed in TABLE 1. The 27 dropouts included 6 with asthma or rhinitis and 6 ex-smokers and were on average 8.7 years younger (95% confidence interval [CI], 2.8 to 14.6 years; $P=.004$) and had been working in a bar for 3.2 fewer years (95% CI, -1.3 to 7.7 years; $P=.16$) than the 77 participants who completed the study. The asthmatic individuals in the subgroup study (5 men, 7 women) had mild to moderate disease according to the Global Initiative for Asthma classification, with a mean (SD) FEV₁ of 99% (14.6%) predicted.²⁵ There was no difference in the dose of inhaled corticosteroid that any

participant was receiving (median, 200 μ g; interquartile range, 0 to 400 μ g) between the 2 points.

Estimated and Measured Exposure to Environmental Tobacco Smoke

There was no difference in the total number of hours worked by participants at any point, although the personal estimate of their total exposure to smoke decreased from 30 hours per week before the introduction of the smoke-free policy to 0 hours per week afterward ($P<.001$) (TABLE 2). Similarly, measured serum cotinine levels decreased from 5.15 ng/mL before the smoke-free policy to 3.22 ng/mL 1 month afterward (-1.93 ng/mL reduction; 95% CI, -2.83 to -1.03 ng/mL; $P<.001$) and 2.93 ng/mL 2 months afterward (-2.23 ng/mL; 95% CI -3.10 to -1.34 ng/mL; $P<.001$). There was no statistical difference ($P=.79$) at the second postlegislation visit between the mean cotinine level in participants who lived with smokers (2.96 ng/mL) and those who did not live with smokers (2.90 ng/mL).

Symptoms

A total of 61 (79.2%) bar workers experienced respiratory or sensory symptoms before the introduction of the smoke-free policy, whereas 1 month afterward, 41 (53.2%) reported any symptom, a -26% change (95% CI, -13.8% to -38.1% ; $P<.001$) (TABLE 3). At 2 months after introduction of the smoke-free policy, this improvement was maintained, with 38 (46.8%) of participants reporting any symptom (total change from baseline, -32.5% ; 95% CI, -19.8% to -45.2% ; $P<.001$). The median number of symptoms experienced by participants decreased from 2 at 1 month before the ban to 1 a month after the ban and then to 0 at 2 months after the ban ($P=.001$ and $P<.001$, respectively). Furthermore, there were significant improvements in the percentage of bar workers experiencing respiratory (total reduction, -20.8% ; 95% CI, -7.6% to -33.9% ; $P=.005$) and sensory (total reduction, -31.2% ; 95% CI, -18.1% to -44.3% ; $P<.001$) symptoms at 1 month after the

introduction of the smoke-free policy, and this improvement was also sustained at 2 months (-35.1%; 95% CI, -22.2% to -47.9%; $P < .001$; and -35.1%; 95% CI, -21.7% to -48.4%, respectively).

A separate analysis of all participants ($n=90$) who undertook the first postlegislative visit revealed a reduction of 36.7% (95% CI, -48.8% to -24.6%; $P < .001$) in all symptoms, with a 17.8% (95% CI, -30.3% to -5.2%; $P = .01$) reduction and a 31.1% reduction (95% CI, -43.3% to -18.9%; $P < .001$) in respiratory symptoms and sensory symptoms, respectively, which is comparable to the findings with the original per-protocol data set ($n=77$) for those completing all visits.

For the asthmatic subgroup, there was a significant improvement in Juniper Mini Asthma Quality of Life Questionnaire score of 7.3 points (95% CI, 0.1 to 14.6 points; $P = .049$) between the month before and 2 months after implementation of the smoke-free policy (TABLE 4). Within the individual domains of the questionnaire, there was a significant improvement in the scores, attributable to environmental factors (2.0-point difference; 95% CI, 0.7 to 3.3 points; $P = .005$).

Lung Function

FEV₁ improved by 1 month after the introduction of the smoke-free policy compared with preban values in the study group as a whole (an increase of 8.2% predicted; 95% CI, 3.9% to 12.4%; $P < .001$), and this improvement was evident in asthmatic individuals (15.7% increase; 95% CI, 5.7% to 25.7%; $P = .008$) and in otherwise healthy individuals (5.7% increase; 95% CI, 1.0% to 10.3%; $P = .04$) (Table 3). Repeated measurements at 2 months confirmed a sustained improvement in this characteristic.

Pulmonary and Systemic Inflammation

There was a 0.80-fold (95% CI, 0.67 to 0.96; $P = .04$) change (ie, a 20% reduction) in FE_{NO} level observed in asthmatic and rhinitic bar workers 1 month after the introduction of the smoke-free policy, and at 2 months, a similar 0.81-fold reduction from preban values was observed (TABLE 5). A similar change was not observed in otherwise healthy volunteers, although these participants had consistently significantly lower values ($P < .001$ preban and 1 month after and $P = .002$ 2 months after) than

those with preexisting asthma and rhinitis at each point. In the asthmatic subgroup, methacholine PC₁₀ and fractional alveolar nitric oxide levels were unaffected by the introduction of the smoke-free policy, with a 1.03 doubling-dilution shift (95% CI, -0.9 to 3.0; $P = .29$) and a 0.97-fold change (95% CI, 0.66 to 1.66; $P = .88$), respectively, from the prelegislation baseline.

Two months after the introduction of the smoke-free policy, the absolute white blood cell count was significantly lower than the prelegislation value by -630 cells/ μ L (95% CI, -1010 to -260 cells/ μ L; $P = .002$), as was the total neutrophil count by -410 cells/ μ L (95% CI, -740 to -90 cells/ μ L; $P = .03$). There was no significant change in C-reactive protein (CRP) values during the same period (Table 5).

COMMENT

Health Effects of the Smoking Ban

This study clearly demonstrates that the recent introduction of legislation in Scotland prohibiting smoking in enclosed public places has led to a rapid and marked improvement in the health of bar workers. Indeed, on average employees had been working in a bar for more than 9 years, but improvements

Table 2. Potential and Reported Exposure to ETS and Serum Cotinine Levels Before and After Introduction of the Smoking Ban (N=77)

	Before Ban	1 Month After Ban	Change From Baseline (95% CI)	P Value	2 Months After Ban	Change From Baseline (95% CI)	P Value
No. of hours at work per week	32.6 (1.8)	31.9 (1.8)	-0.7 (-2.3 to 0.8)	.25	31.8 (1.8)	-0.8 (-2.8 to 1.1)	.91
Participant's estimate of exposure to ETS, median (IQR), h*	30 (20 to 46.5)	0	-30 (-40 to -23)	<.001	0 (0 to 1.75)	-30 (-38 to -23)	<.001
Serum cotinine levels, mean (SD), ng/mL	5.15 (0.353)	3.22 (0.132)	-1.93 (-2.83 to -1.03)	<.001	2.93 (0.09)	-2.22 (-3.10 to -1.34)	<.001

Abbreviations: CI, confidence interval; ETS, environmental tobacco smoke; IQR, interquartile range.

*The estimate of smoke exposure represents the total at work and elsewhere, including the home environment.

Table 3. Symptoms and Spirometry Before and After Introduction of the Smoking Ban (N=77)

	Before Ban	1 Month After Ban	Change From Baseline (95% CI)	P Value	2 Months After Ban	Change From Baseline (95% CI)	P Value
Symptoms, % (No.)							
Any	79.2 (61)	53.2 (41)	-26 (-13.8 to -38.1)	<.001	46.8 (38)	-32.5 (-19.8 to -45.2)	<.001
Respiratory	62.3 (48)	41.5 (32)	-20.8 (-7.6 to -33.9)	.005	27.3 (21)	-35.1 (-22.2 to -47.9)	<.001
Sensory	71.4 (55)	40.3 (31)	-31.2 (-18.1 to -44.3)	<.001	36.4 (28)	-35.1 (-21.7 to -48.4)	<.001
No. of symptoms, median (IQR)	2 (1 to 4)	1 (0 to 3)	-1 (-2 to 0)	.001	0 (0 to 2)	-2 (-2 to 0)	<.001
FEV ₁ , mean (SE), %							
Entire cohort	96.6 (2.26)	104.8 (2.53)	8.2 (3.9 to 12.4)	<.001	101.7 (1.87)	5.1 (2.1 to 8.0)	.002
Otherwise healthy	98.7 (2.52)	104.4 (2.94)	5.7 (1.0 to 10.3)	.04	102.1 (2.16)	3.38 (0.64 to 6.12)	.03
Asthma	90.3 (4.86)	106.1 (5.06)	15.7 (5.7 to 25.7)	.008	100.5 (3.83)	10.2 (1.6 to 18.8)	.046

Abbreviations: CI, confidence interval; FEV₁, forced expiratory volume in the first second; IQR, interquartile range.

in health were evident only 1 month after the introduction of a smoke-free policy. There appeared to be an initial improvement in sensory symptoms at 1 month after the smoke-free policy was introduced, with respiratory symptoms improving shortly after this, at 2 months. These data are in agreement with those previously reported, which showed that after the introduction of similar legislation in the Republic of Ireland and the United States, pulmonary and sensory symptoms of hospitality workers improved, as did objective measures of secondhand smoke exposure.^{11,13,26}

Sustained and significant improvements were also observed in the spirometry data for asthmatic and nonasthmatic participants after introduction of the smoke-free policy. A number of previously published studies have reported impaired pulmonary function in adults and children in association with exposure to secondhand smoke, and a study similar to ours, carried out in the United States, showed small improvements in the forced vital capacity of bar workers 2 months after the introduction of a smoke-free policy.^{12,27,28} The

preserved FEV₁ in our asthmatic population reinforces the mild to moderate nature of the disease in this group, although their baseline levels of methacholine hyperresponsiveness and FE_{NO} were markedly abnormal, in keeping with the presence of active inflammation. It is conceivable that more severely affected patients would have been precluded from undertaking this type of work before now because of the inevitable exposure to secondhand smoke and the potential deleterious effects on their health.

Effect on Inflammation

Whereas previous studies into the effect of smoke-free legislation have concentrated on reported symptoms and cotinine levels, none have thus far quantified the effect on objective inflammatory biomarkers, nor have they gathered sequential data over time.^{11-13,26} FE_{NO} is an established surrogate measure of airway inflammation, and secondhand smoke has been shown to suppress FE_{NO} in healthy volunteers.²⁹ There is less evidence about the effects of tobacco smoke on FE_{NO} in asthmatic individuals, although a re-

cent report in actively smoking asthmatic individuals found no difference in levels after smoking cessation, which is in contrast to our findings of reduced levels in asthmatic individuals after removal of secondhand smoke from the environment.³⁰ Although increased bronchial methacholine responsiveness has been noted in nonasthmatic smokers over time compared with those who stop smoking and an improvement in responsiveness is associated with stopping smoking, until now no data existed on the influence of secondhand smoke on this characteristic, although we found no improvement in our cohort.^{31,32}

There was a reduction in peripheral total white blood cell count and neutrophil count at 2 months after the introduction of the smoke-free policy. This result is in keeping with results from the ATTICA study, which found increased total white blood cell characteristics in participants exposed to secondhand smoke compared with those not exposed, approximately the same order as the reduction we found after implementation of the ban (600 cells/ μ L).¹⁵ Although there was no change in CRP levels at any point, the levels detected in our participants at baseline were low to begin with. In addition, other studies have documented only small quantifiable differences between smokers and nonsmokers, and in prospective trials there has been no change in CRP levels after 1 year of validated smoking cessation among participants.^{15,33,34}

Table 4. Juniper Mini Asthma Quality of Life Questionnaire Scores Before and After Introduction of the Smoking Ban in the Asthmatic Subgroup (n=12)

	Preban	Postban	Difference (95% Confidence Interval)	P Value
Total	80.2 (4.4)	87.5 (5.4)	7.3 (0.1 to 14.6)	.049
Symptoms	24.8 (1.9)	28.2 (2.1)	3.4 (-0.1 to 6.9)	.06
Activity	24.1 (1.1)	24.8 (1.3)	0.7 (-0.8 to 2.2)	.35
Emotion	16.6 (1.2)	17.8 (1.3)	1.3 (-0.8 to 3.3)	.20
Environment	14.8 (0.7)	16.8 (0.9)	2.0 (0.7 to 3.3)	.005

Table 5. Airway and Systemic Inflammation Before and After Introduction of the Smoking Ban (N=77)

	Before Ban	1 Month After Ban	Change From Baseline (95% CI)	P Value	2 Months After Ban	Change From Baseline (95% CI)	P Value
Exhaled nitric oxide, mean (SE), ppb							
Entire cohort (n = 77)	19.6 (18.0 to 21.2)	19.3 (18.1 to 20.7)	1.01 (0.92 to 1.11)	.1	18.7 (17.2 to 20.3)	0.94 (0.85 to 1.04)	.51
Otherwise healthy (n = 54)	15.3 (14.0 to 16.7)	16.6 (15.3 to 17.7)	1.09 (0.98 to 1.20)	.25	15.7 (14.4 to 17.1)	1.01 (0.91 to 1.12)	>.99
Asthma or rhinitis (n = 23)	34.3 (30.4 to 38.6)*	27.4 (24.0 to 31.3)*	0.80 (0.67 to 0.96)	.04	27.6 (23.6 to 32.2)*	0.81 (0.64 to 1.01)	.12
Total white blood cells, mean (SE), cells/ μ L	7610 (250)	7290 (240)	-310 (-660 to -30)	.15	6980 (260)	-630 (-1010 to -260)	.002
Neutrophils, mean (SE), cells/ μ L	4440 (170)	4260 (150)	-180 (-480 to 120)	.47	4030 (180)	-410 (-740 to -90)	.03
CRP, mean (SE), mg/L	0.99 (0.84 to 1.15)	1.23 (1.03 to 1.46)	1.24 (0.93 to 1.67)*	.14	1.11 (0.96 to 1.28)	1.11 (0.91 to 1.36)*	.30

Abbreviations: CI, confidence interval; CRP, C-reactive protein.

*Significant difference from otherwise healthy population, $P < .001$ preban and 1 month after the ban, $P = .002$ 2 months after the ban.

Asthma and Rhinitis Subgroup

Although effects were observed in all bar workers, those with preexisting asthma or rhinitis had the largest gains in health. Although the sample size precluded separate analysis of this group with regard to perceived symptoms, the Juniper questionnaire data suggest that the introduction of the smoke-free policy led to improvements in overall quality of life in asthmatic bar workers. Indeed, a 0.5-point improvement is regarded as a clinically significant change in this tool, and our cohort had an average increase of 7.3. Perhaps unsurprisingly, the greatest improvements were observed in the environmental domain of the questionnaire, which includes symptoms at work. Similarly, although an improvement in FEV₁ was observed in the entire cohort, the greatest gains were in the asthmatic cohort (Table 3). For participants with preexisting asthma or rhinitis, there was also the additional benefit of reduced respiratory tract inflammation, as evidenced by the reduction in FE_{NO} that was not observed in otherwise healthy individuals, which is important because long-term indolent inflammation can lead to airway remodeling and fixed obstruction, even in mild to moderate disease.³⁵ No significant improvement in airway hyperresponsiveness was detected, which is somewhat surprising because this is more closely related to asthmatic symptoms than spirometric indices. This lack of change is possibly because response to bronchial challenge is not as sensitive to small changes in airway inflammation as is FE_{NO}.³⁶

Limitations of the Study

The dropout rate of 27% was substantial, although we had anticipated this because of the often transient nature of the workforce employed in the bar trade. There was also undoubtedly an element of self-selection bias among participants who undertook the study because there was a larger proportion of participants with preexisting asthma or rhinitis in the cohort who underwent 3 visits (23/77) compared with

those that dropped out of the study (6/28). Employees experiencing symptoms that they attribute to their place of work may have been more enthusiastic about undertaking such a study and therefore more likely to complete the protocol, which is possibly reflected in the discrepancy between the large changes in subjective symptoms compared with the smaller alterations in objective measurements. We have not obtained data from more than 2 months after the introduction of smoke-free policy, and it is conceivable that even greater alterations in all the measured characteristics would be observed during a longer period. This potential is particularly relevant when asthmatic airway inflammation is evaluated and may partly explain the observed change in FE_{NO} but not methacholine responsiveness, which may take longer to improve. Also, some of the improvements in FEV₁ observed in the asthmatic and nonasthmatic groups may be attributable to a "learning effect" over time, and without a control group, this is difficult to disprove.

Although changes in serum cotinine levels were detected, the levels did not decrease compared with those observed in nonsmokers, who generally have levels of less than 1 ng/mL, although greater decreases may have been observed during a longer period.⁵ Alternatively, persistently increased cotinine levels detected after the introduction of the smoke-free legislation suggest that some continual low-grade exposure may still be present from environments other than the workplace. Because the sample size of asthmatic individuals was relatively small, the study may have been insufficiently powered to detect small but significant changes in the characteristics measured, and inclusion in a trial of this nature may lead to increased compliance with prescribed medication. This potential confounding factor is particularly important when the FE_{NO} data for asthmatic individuals are interpreted because this measurement has a steep dose-response relationship with inhaled corticosteroid.

CONCLUSIONS

The introduction of a Scottish ban on smoking in enclosed public places has led to a reduction in symptoms attributable to secondhand smoke exposure in bar workers and improved pulmonary function. In addition, there was a reduction in circulating inflammatory cells and serum cotinine levels. Employees with asthma also benefited from an improved quality of life, as well as reduced airway inflammation in terms of reduced FE_{NO} levels.

Author Contributions: Dr Menzies had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Menzies, Nair, Williamson, Schembri, Barnes, Fardon, Lipworth.

Acquisition of data: Menzies, Schembri, Al-Khairalla, Barnes, Magee.

Analysis and interpretation of data: Menzies, McFarlane, Lipworth.

Drafting of the manuscript: Menzies, Lipworth.

Critical revision of the manuscript for important intellectual content: Menzies, Nair, Williamson, Schembri, Al-Khairalla, Barnes, Fardon, McFarlane, Magee, Lipworth.

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