

Bar Workers' Exposure to Second-Hand Smoke: The Effect of Scottish Smoke-Free Legislation on Occupational Exposure

SEAN SEMPLE^{1,2*}, LAURA MACCALMAN², AUDREY ATHERTON NAJI¹, SCOTT DEMPSEY², SHONA HILTON^{1,3}, BRIAN G. MILLER² and JON G. AYRES¹

¹Department of Environmental and Occupational Medicine, Liberty Safe Work Research Centre, University of Aberdeen, Foresterhill Road, Aberdeen AB25 2ZP, UK; ²Institute of Occupational Medicine, Research Avenue North, Edinburgh EH14 4AP, UK; ³MRC Social and Public Health Sciences Unit, 4 Lillybank Gardens, Glasgow G12 8RZ, UK

Received 23 July 2007; in final form 12 August 2007; published online 10 September 2007

Objectives: To examine changes in bar workers' exposure to second-hand smoke (SHS) over a 12-month period before and after the introduction of Scottish smoke-free legislation on the 26 March 2006.

Methods: A total of 371 bar workers were recruited from 72 bars in three cities: Aberdeen, Glasgow, Edinburgh and small towns in two rural regions (Borders and Aberdeenshire). Prior to the introduction of the smoke-free legislation, we visited all participants in their place of work and collected saliva samples, for the measurement of cotinine, together with details on work patterns, self-reported exposure to SHS at work and non-work settings and smoking history. This was repeated 2 months post-legislation and again in the spring of 2007. In addition, we gathered full-shift personal exposure data from a small number of Aberdeen bar workers using a personal aerosol monitor for fine particulate matter (PM_{2.5}) at the baseline and 2 months post-legislation visits.

Results: Data were available for 371 participants at baseline, 266 (72%) at 2 months post-legislation and 191 (51%) at the 1-year follow-up. The salivary cotinine level recorded in non-smokers fell from a geometric mean of 2.94 ng ml⁻¹ prior to introduction of the legislation to 0.41 ng ml⁻¹ at 1-year follow-up. Paired data showed a reduction in non-smokers' cotinine levels of 89% [95% confidence interval (CI) 85–92%]. For the whole cohort, the duration of workplace exposure to SHS within the last 7 days fell from 28.5 to 0.83 h, though some bar workers continued to report substantial SHS exposures at work despite the legislation. Smokers also demonstrated reductions in their salivary cotinine levels of 12% (95% CI 3–20%). This may reflect both the reduction in SHS exposure at work and falls in active cigarette smoking in this group. In a small sub-sample of bar workers, full-shift personal exposure to PM_{2.5}, a marker of SHS concentrations, showed average reductions of 86% between baseline and 2 months after implementation of the legislation.

Conclusions: Most bar workers have experienced very large reductions in their workplace exposure to SHS as a result of smoke-free legislation in Scotland. These reductions have been sustained over a period of 1 year.

Keywords: cotinine; particulate matter; second-hand smoke

INTRODUCTION

Exposure to second-hand smoke (SHS) has been identified as causing lung cancer (Hackshaw, 1997), cardiovascular disease (Law *et al.*, 1997) and a range

of other health problems including exacerbation of asthma (Eisner, 2005) and even acute myocardial ischaemia (Otsuka *et al.*, 2001) among non-smokers. Recent evidence has suggested that cardiovascular risks from exposure to SHS are as high as 80–90% of those experienced by chronic active smokers (Barnoya and Glantz, 2005). Public health policy in a number of industrialized countries has moved

*Author to whom correspondence should be addressed.
Tel: +44(0)1224 558188; fax: +44(0)1224 551826;
e-mail: sean.semple@abdn.ac.uk

to control exposure to SHS, with recent smoke-free working environments introduced across many European Union (EU) countries, Australia, New Zealand and some states of the United States. The Smoking, Health and Social Care Act (Scotland) of 2005 prohibited smoking in enclosed or substantially enclosed public places in Scotland from the 26 March 2006 and more recent legislation has been passed to introduce similar measures in Wales, Northern Ireland and England.

Exposure to SHS in the workplace is a major problem. A recent review by Jaakkola and Jaakkola (2006) estimated that ~7.5 million workers in the EU are exposed to SHS at work. While national smoke-free legislation will reduce the number of workers exposed in many countries, there continue to be many areas of the world where employees remain exposed to SHS while at work. Workers in the hospitality sector have among the highest exposures to SHS of all occupational groups (Howard, 2004). A study in London showed that non-smoking bar workers have salivary cotinine levels of four times the level of non-smokers who live with partners who smoke, and almost 10 times the levels of non-smokers living in non-smoking households (Jarvis, 2001). Data from New Zealand indicate that non-smoking hospitality workers in establishments that permit smoking have salivary cotinine levels of between 3 and 4 times those of non-smoking workers in smoke-free premises (Bates *et al.*, 2002). Work to estimate the number of deaths attributable to SHS exposure has recently been completed, with one analysis (Hole, 2005) indicating that between 1500 and 2000 non-smokers' deaths per year in Scotland are attributable to SHS exposure. Jamrozik (2005) suggest that, prior to the introduction of the smoke-free legislation in England, Scotland, Wales and Northern Ireland, ~54 hospitality workers died as a result of their exposure to SHS every year in the United Kingdom.

Investigations of the effects of the Irish smoke-free legislation, introduced in 2004, showed an 80% reduction in salivary cotinine levels in a group of non-smoking bar workers (Allwright *et al.*, 2005). Median salivary cotinine values fell from 29.0 nmol l⁻¹ (5.1 ng ml⁻¹) to 5.1 nmol l⁻¹ (0.90 ng ml⁻¹). A linked study (Goodman *et al.*, 2007) also demonstrated a 99% fall in Dublin bar workers' self-reported duration of exposure to SHS in the workplace from a mean of 40.5 h pre-ban to 0.42 h post-ban and a fall in fine particulate matter (PM_{2.5}) levels in 42 public houses of ~83%. Another Irish study by Mulcahy *et al.* (2005) reported that median salivary cotinine levels in 35 non-smoking hotel workers fell from 1.6 ng ml⁻¹ before the ban to 0.5 ng ml⁻¹ after the ban. Self-reported SHS exposure at work also fell from a median of 30 h week⁻¹ to zero, while airborne levels of nicotine in a random

sample of 20 bars showed an 83% reduction. A previous small study of bar workers in Dundee, Scotland, showed only a 43% reduction in serum cotinine levels in non-smoking bar workers at 2 months after introduction of smoke-free legislation despite large falls (median: 30 h week⁻¹ to zero post-ban) in self-reported exposure to SHS (Menzies *et al.*, 2006).

The Bar Workers' Health and Environmental Tobacco Smoke Exposure (BHETSE) study is part of an integrated programme of studies that aim to evaluate the effects of the smoke-free legislation in Scotland (Haw *et al.*, 2006). The BHETSE study gathered details from a cohort ($n = 371$ at baseline) of bar workers over a 12-month period and, as such, is one of the largest and longest longitudinal studies of bar workers in relation to smoke-free legislation. Previously published results from the BHETSE study have shown the changes in SHS measured in Scottish bars immediately before and up to 2 months after the 26 March 2006 (Semple *et al.*, 2007). PM_{2.5} concentrations measured discreetly for 30-min periods in 41 bars were shown to have fallen from an average level of 246 to 20 µg m⁻³, a reduction of 86%, at 2 months post-implementation. We have also examined bar workers' attitudes to SHS exposure and the legislation and showed that smoke-free legislation was supported by 69% of bar workers prior to implementation rising to 79% 2 months post-ban (Hilton *et al.*, 2007).

This paper aims to examine changes in exposures to SHS among the BHETSE cohort as found before and shortly after implementation of Scottish smoke-free legislation and re-examined again at 12 months post-baseline.

METHODS

Recruitment

All bars from within designated postcode areas within three large cities (Glasgow, Edinburgh, Aberdeen) and small towns (population < 3000) in the Aberdeenshire and Borders areas within Scotland were entered in to a study database. A total of 861 bars from a broad range of socioeconomic areas and types of bars in urban, semi-urban and rural settings were available for selection within these areas. A total of 159 bars were randomly selected in sequence in order to recruit a target of 120 bar workers from each of the three geographical areas (Glasgow, Edinburgh/Borders, Aberdeen/Shire). Each selected bar was contacted by telephone and invited to take part in the study. Bar managers who expressed an interest were sent letters and other material describing the study for distribution to all their bar staff. With permission from the bar managers, a researcher visited the bars at pre-arranged times to maximize the number of bar staff recruited at each visit. From the 159 bars we contacted, 72 (45%) bars agreed to participate.

We carried out convenience sampling between 7 January and 25 March 2006 of a total of 371 bar workers (including managers, owners and bar staff), who were available and willing to take part at the time of our visits, across a range of weekday and weekend shift times. Participants were followed up on two further occasions between May and July 2006 and again between January and March 2007. At all three visits, participants were asked to complete a questionnaire providing demographic details, smoking history, health symptom, exposure and attitudinal data. In addition, we asked participants to carry out a forced expiratory manoeuvre to measure lung function and to provide a saliva sample for analysis of salivary cotinine.

Exposure Assessment

Questionnaire. The full questionnaire used at the baseline survey is available as supplementary data at *Annals of Occupational Hygiene* online. The health elements of this questionnaire are derived from a similar instrument developed by Eisner *et al.* (1998) in their study of the effects of smoke-free laws on Californian bar workers' health. The questionnaire also contained several questions on exposure to SHS. To determine changes in duration of exposure to SHS participants were asked, 'During the past 7 days, how many hours were you exposed to other people's smoke at work?'. There were also questions about SHS exposure outside the working environment. Details of smoking habits, the number of cigarettes smoked and the use of nicotine replacement therapy (NRT) were also gathered.

Salivary cotinine measurement. At each of the three surveys, non-stimulated saliva samples were collected from participants using a salivette (Sarstedt Ltd, Leicester, UK) following the protocol used for salivary cotinine measurement in the Scottish Health Survey (The Scottish Executive, 2005). Samples were sent to ABS Laboratories, London, UK, and analysed for cotinine using a previously reported rapid gas-liquid chromatographic technique (Feyerabend and Russell, 1990). Results less than the limit of detection (LOD) (0.1 ng ml^{-1}) were assigned a value of half the LOD. For the purposes of analysis, we compared the self-report of smoking behaviour (never, ex-smoker, regular and occasional smoker) with the salivary cotinine level. A cut-off of 20 ng ml^{-1} salivary cotinine as the level above which active smoking is likely to have taken place has been previously used for bar workers (Allwright *et al.*, 2005) and we used this concentration in creating sub-groups of confirmed smokers/non-smokers. When considering the saliva cotinine level, we removed those who had reported using NRT. We also removed those using NRT when using saliva cotinine to confirm the self-reported smoking status.

Airborne concentration of $PM_{2.5}$. In Aberdeen, we also recruited nine bar workers to wear a personal

aerosol monitor (TSI Sidepak AM510) fitted with a $PM_{2.5}$ size selective impactor for the duration of a working shift. These measurements were carried out prior to the introduction of the legislation and then again in the 2-month post-ban phase of the study. The monitor was calibrated to zero before use and the airflow rate set at 1.71 min^{-1} using a Drycal DC Lite flowmeter. A short length of Tygon tubing was used to sample air from the worker's breathing zone with the monitor usually located on a belt around the waist. The device was switched on at the beginning of the work shift and set to log $PM_{2.5}$ levels at 1-min intervals. Raw data were corrected to take account of the density of SHS particles by applying a correction factor of 0.295 in accordance with the device calibration instruction note and previous work by Repace (2006).

Statistical analysis

Cotinine levels are summarized by geometric mean (GM) and geometric standard deviation (GSD). Analysis of the change in the cotinine levels was performed by paired *t*-tests on the log values and results are summarized as the percentage of cotinine reduction with 95% confidence intervals (CI), based on the standard errors of the log differences. Analyses of changes in cigarette consumption were similarly carried out through paired comparisons, on the original scale.

RESULTS

Description of cohort and follow-up

Overall, we recruited some 371 individuals from a total of 72 bars across Scotland. We followed up 266 (72%) of these individuals at 2-month post-implementation and 191 (51%) of the original cohort at 1-year post-baseline. Characteristics of the participants at each phase of the study are presented in Table 1. The mean age of participants at all three surveys was <30 years (at the baseline interview) with approximately equal numbers of males and females seen at each phase. As would be anticipated, those who had longer bar work experience and who were owners, managers or permanent bar staff were more likely to be available at follow-up than less experienced, temporary staff. By self-report, 55% of our cohort described themselves as regular or occasional smokers at Phase 1, much higher than the 26% for the Scottish population in general (The Scottish Executive, 2005).

Salivary cotinine results

Valid salivary cotinine data were available for 301 (81%) of the total cohort seen at baseline (53 insufficient samples; 2 refused and 15 excluded due to NRT use), 220 (83%) at Phase 2 (22 insufficient samples;

Table 1. Characteristics of the cohort seen at Phase 1, 2 and 3

Characteristics ^a	Phase 1		Followed up at Phase 2		Followed up at Phase 3 (including 14 not seen at 2)	
	Mean	Range	Mean	Range	Mean	Range
Age	27.9	15–70	28.7	15–67	29.5	15–67
Years worked in bars	7.0	0–43	7.5	0–43	8.2	0–43
Years worked in this bar	3.0	0–37	3.4	0–37	3.9	0–37
Hours worked per week	30.8	0–75	31.7	2–75	32.6	2–75
	<i>n</i>	% ^b	<i>n</i>	%	<i>n</i>	%
Sex						
Male	192	52	131	49	97	51
Female	179	48	135	51	94	49
Smoking status						
Regular smoker	158	43	104	39	81	42
Occasional smoker	43	12	31	12	19	10
Ex-smoker	58	16	48	18	34	18
Non-smoker	110	30	83	31	57	30
Not answered	2	1	0	0	0	0
Location						
Aberdeen/Shire	120	32	91	34	73	38
Glasgow	121	33	91	34	54	28
Edinburgh/borders	130	35	84	32	64	34
Education level						
School	81	22	63	24	51	27
Further education college	107	29	74	28	51	27
University	170	46	119	45	85	45
Postgraduate	13	3	10	4	4	2
Job						
Owner	20	5	15	6	14	7
Manager	74	20	64	24	50	26
Permanent bar staff	216	58	144	54	83	43
Temporary bar staff	34	9	14	5	6	3
Other	26	7	12	5	20	10
Not answered	1	0	17	6	18	9
Total	371		266		191	

^aFor ease of comparison, data on age, years/hours worked and education level are those provided by participants when asked at Phase 1 interview. All other parameters are those provided by the participant at each of Phase 1, 2 or 3.

^bPercentages may not add to 100 due to rounding.

3 refused and 21 excluded due to NRT use) and 174 (91%) at Phase 3 (14 insufficient samples; zero refused and three excluded due to NRT use). Data were available for a similar proportion of smokers and non-smokers at baseline (84% versus 84%) but were available for proportionately more smokers than non-smokers at 1-year follow-up (97% versus 88%). This difference at Phase 3 was due to 12 samples from non-smokers versus 2 from smokers being of insufficient saliva volume.

Table 2 presents summary data for cotinine levels based on classification by self-reported smoking status at each stage, and then for the sub-groups where cotinine results confirmed the self-report (<20 ng ml⁻¹ for never and ex-smokers; ≥ 20 ng ml⁻¹ for regular and occasional smokers).

At Phase 1, the GM cotinine concentrations of those classifying themselves as never smokers (*n* = 92) was 3.42 and 3.77 ng ml⁻¹ for ex-smokers (*n* = 43). These compared to 23.6 ng ml⁻¹ for occasional smokers (*n* = 34) and 234 ng ml⁻¹ for regular smokers (*n* = 130).

Figure 1a compares the salivary cotinine concentrations at Phase 1 and 3, among subjects who were confirmed non-smokers at both surveys and not using any NRT. Each triangle represents a study subject, and points below the line of equality indicate a drop in cotinine level over the year of follow-up. Equal distances from the line represent equal proportional reductions in concentration, as indicated by the parallel lines showing 50, 90 and 99% reduction. There were no increases, and almost all subjects recorded

Table 2. Salivary cotinine levels (ng ml⁻¹) by self-reported and confirmed smoking status at each phase

	Phase 1			Phase 2			Phase 3		
	<i>n</i>	GM	GSD	<i>n</i>	GM	GSD	<i>n</i>	GM	GSD
All	301	27.2	9.26	220	11.4	20.1	174	10.6	24.2
Never smokers	92	3.4	2.44	71	0.7	3.1	48	0.3	3.2
Ex-smokers	43	3.8	4.05	35	1.3	7.5	31	0.9	6.6
Non-smokers < 20 ng ml ^{-1a}	126	2.9	2.28	102	0.7	3.2	77	0.4	3.7
Occasional smokers	34	23.6	5.21	22	13.9	10.1	19	26.2	5.9
Regular smokers	130	234.1	2.03	92	230.6	2.0	76	218.2	1.9
Current smokers ≥ 20 ng ml ^{-1b}	149	207.4	2.1	104	209.1	2.0	88	190.7	2.0

^aNon-smokers are never and ex-smokers combined.

^bCurrent smokers are regular and occasional smokers combined.

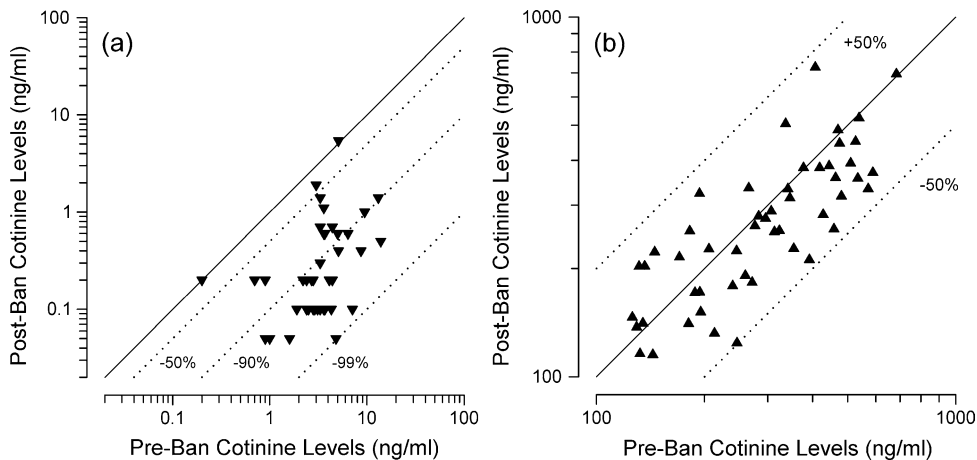


Fig. 1. Comparison of salivary cotinine levels for confirmed non-smokers (a) and confirmed smokers (b) seen at Phase 1 and 3. The data are presented on a log scale and the dashed lines represent the 50, 90 and 99% reduction lines.

reductions in cotinine concentrations >50%. A few subjects showed little change, but no allowance has been made here for the effects of SHS acquired away from work, e.g. in living with a smoker. Table 3 summarizes the changes between phases and shows that the GM reduction in Fig. 1a was 89% (95% CI 85–92%). The majority of the change occurred in the few months following the legislation's introduction, but there was a further significant decrease by the 1-year follow-up.

Figure 1b shows a similar comparison between cotinine concentrations at Phase 1 and 3, in subjects who were confirmed smokers at both surveys and who did not use NRT. Cotinine levels were much higher in smokers, and the scale is very different from that of Fig. 1a. Here no subject showed more than a 50% difference. However, there was a suggestion of some reduction overall, with 18 points above and 42 points below the line. Table 3 shows that the GM concentration in all 60 smokers reduced by 12%, and the 95% CI excluded zero, so the change would be judged statistically significant.

Change in smoking habits of bar workers

Self-reported smoking status identified a total of 14 subjects who had stopped smoking between Phase 1 and 2 and a further 6 who stopped between Phase 2 and 3. Additionally, one participant (who was not seen at Phase 2) stopped between Phase 1 and 3. This total of 21 represents ~10% of all those who reported smoking at Phase 1 ($n = 201$). However, eight participants who reported being ex- or never smokers at Phase 1 were current smokers by Phase 2 with a further five ex-smokers becoming current smokers by Phase 3. In summary, our two follow-up surveys showed a net reduction of eight bar workers who classified themselves as current smokers. This represents ~4% of those who considered themselves to be smokers at baseline ($n = 201$). Although based on a small number of changes, this is broadly consistent with the change in adult smoking prevalence from 26% in 2005 to 25% in 2006—an ~4% reduction in the number of people who smoke (The Scottish Executive, 2006, 2007).

At the Phase 1 survey, those describing themselves as regular smokers reported a wide range of cigarette consumption, ranging from 0 (in a cigar smoker) to 60 a day, with an arithmetic mean (AM) of 15. Those describing themselves as occasional smokers reported consumption ranging from 0 to 20 and an AM of 4. Table 4 summarizes the changes in cigarette consumption between surveys for self-described regular smokers with cotinine concentrations ≥ 20 ng ml⁻¹ and for the few occasional smokers with cotinine concentrations in this range and who were not using NRT. Overall, there was a statistically significant drop of 2.5 cigarettes per day between baseline and 1-year follow-up, and the greater part of this was achieved before the Phase 2 survey.

Duration of SHS exposure

Table 5 presents details of the reduction in self-reported duration of SHS exposure at work (in the last 7 days). For all of the participants, the AM re-

duced from 28.5 h to ~ 1.5 h at Phase 2 and then to 0.8 h by 1-year follow-up. The fall was similar in size and pattern in both non-smoking and smoking bar workers. The paired comparisons (Table 6) show a statistically significant decrease in self-reported SHS exposure at work of ~ 30 h a week, for both groups.

The duration of SHS exposure at Phase 2 and 3 was higher in smokers, probably due to smokers choosing to take cigarette breaks in areas such as beer gardens and at doorways where customers smoke. The pairwise difference in SHS exposure at work is similar for both smokers and non-smokers.

Changes in personal full-shift PM_{2.5} exposures

A total of nine bar workers agreed to wear a TSI AM510 Personal aerosol monitor for a period representative of a full shift at Phase 1 of the study. Sampling duration ranged from ~ 5 to 6.5 h (mean 6.25 h). Sampling was repeated in six of these nine bar

Table 3. Change (% reduction) in salivary cotinine concentrations (grouped by self-reported smoking status, confirmed by saliva cotinine)

	Between Phase 1 and 2			Between Phase 2 and 3			Between Phase 1 and 3		
	<i>n</i>	% Reduction	95% CI	<i>n</i>	% Reduction	95% CI	<i>n</i>	% Reduction	95% CI
Non-smokers (<20 ng ml ⁻¹)	74	78	71 to 84	50	45	27 to 61	57	89	85 to 92
Current smokers (≥ 20 ng ml ⁻¹)	78	6	-2 to 13	61	8	-2 to 16	60	12	3 to 20

Table 4. Change in number of cigarettes smoked per day (grouped by self-reported smoking status, confirmed by saliva cotinine)

	Between Phase 1 and 2			Between Phase 2 and 3			Between Phase 1 and 3		
	<i>n</i>	AM	95% CI	<i>n</i>	AM	95% CI	<i>n</i>	AM	95% CI
Regular smokers	73	-1.6	-2.8 to -0.4	57	0.2	-0.9 to 1.3	55	-2.7	-4.3 to -1.1
Occasional smokers	5	0.5	-2.3 to 3.3	4	-0.75	-4.7 to 3.2	5	-1.4	-2.8 to -0.1
Current smokers ^a	78	-1.5	-2.6 to 0.4	61	0.13	-0.9 to 1.2	60	-2.5	-4.0 to -1.1

^aCurrent smokers are regular smokers and occasional smokers combined.

Table 5. Duration of SHS exposure (hours) at work (last 7 days)

	Phase 1			Phase 2			Phase 3		
	<i>n</i>	AM	Range	<i>n</i>	AM	Range	<i>n</i>	AM	Range
All	363	28.5	0.0-105	260	1.46	0-39.0	184	0.83	0-48
Smokers	196	29.3	0.0-105	132	1.94	0-33.5	97	1.4	0-48
Non-smokers	165	27.7	0.0-90	128	0.96	0-39.0	87	0.21	0-8

Smoking status groups are based on self-report.

Table 6. Change in duration of SHS exposure (hours) at work (last 7 days)

	Between Phase 1 and 2			Between Phase 2 and 3			Between Phase 1 and 3		
	<i>n</i>	AM	95% CI	<i>n</i>	AM	95% CI	<i>n</i>	AM	95% CI
All	219	-28.7	-31.2 to -26.2	142	-0.16	-1.3 to 1.0	152	-30.5	-33.5 to -27.5
Smokers	111	-28.7	-32.4 to -25.0	74	-0.16	-2.3 to 2.0	81	-30.4	-34.8 to -26.0
Non-smokers	108	-28.7	-32.1 to -25.3	68	-0.16	-0.7 to 0.4	71	-30.6	-34.7 to -26.5

workers at Phase 2 with the same shift time and day of week as that selected at Phase 1. Sample durations at Phase 2 averaged ~ 6 h (range ~ 5 to 6.5 h).

The full-shift $PM_{2.5}$ GM concentration for the paired samples ($n = 6$) fell from $202 \mu\text{g m}^{-3}$ pre-ban (range $27\text{--}1070 \mu\text{g m}^{-3}$) to $28 \mu\text{g m}^{-3}$ post-ban (range $8\text{--}90 \mu\text{g m}^{-3}$). Analysis of the logs of the ratios of post-ban to pre-ban concentrations (i.e. analysing paired differences on the log scale) produced a GM ratio of 0.14, which is interpretable as an average 86% reduction in bar workers' personal full-shift $PM_{2.5}$ concentrations.

Figure 2 shows an example of one worker's real-time $PM_{2.5}$ exposure data on the two separate dates of sampling in February 2006 and again in August 2006 and demonstrates the degree of change in personal exposure $PM_{2.5}$ concentrations experienced by bar workers over this time period. Similarly large changes were seen in the other five paired data.

DISCUSSION

Scottish bar workers in this study were exposed to high levels of SHS for much of their work time, prior to the introduction of the smoke-free legislation. The GM salivary cotinine concentration of confirmed non-smokers was 2.94 ng ml^{-1} , very similar to the 2.91 ng ml^{-1} level reported by Jarvis (2001) in his study of 57 non-smoking bar staff in London.

The baseline GM figure of 2.94 ng ml^{-1} for confirmed non-smokers ($n = 126$) in our study was much higher than that seen in non-smokers in the general population. Jarvis (2001) reports data from the 1998 Health Survey for England showing a GM of 0.35 ng ml^{-1} from a population sample of >7000 non-smokers. This large dataset also shows that even non-smokers who were married to smokers ($n = 653$) had GM salivary cotinine levels of 0.99 ng ml^{-1} , about one-third of those of the non-smoking bar workers in the BHETSE study.

Smoke-free legislation led to a large and significant reduction in non-smoking bar workers' cotinine levels. Paired comparisons of cotinine levels between Phase 1 and 3 showed an average 89% (CI 85–92%) fall for non-smokers. These reductions are comparable with the falls seen in Ireland where an 80% fall in the median salivary cotinine concentration was demonstrated among non-smoking bar workers over a similar 1-year follow-up (Allwright *et al.*, 2005; Goodman *et al.*, 2007). Irish hotel workers, who had lower baseline exposures, demonstrated a 48% decrease in the GM concentration (Mulcahy *et al.*, 2005) after the introduction of smoke-free laws. A study of Scottish bar workers in Dundee has previously reported a 43% fall in serum cotinine levels among non-smokers over a 2-month period before and after the legislation (Menzies *et al.*, 2006). It is not clear why the Dundee sample ($n = 77$) showed reductions of about one-half of those found in the

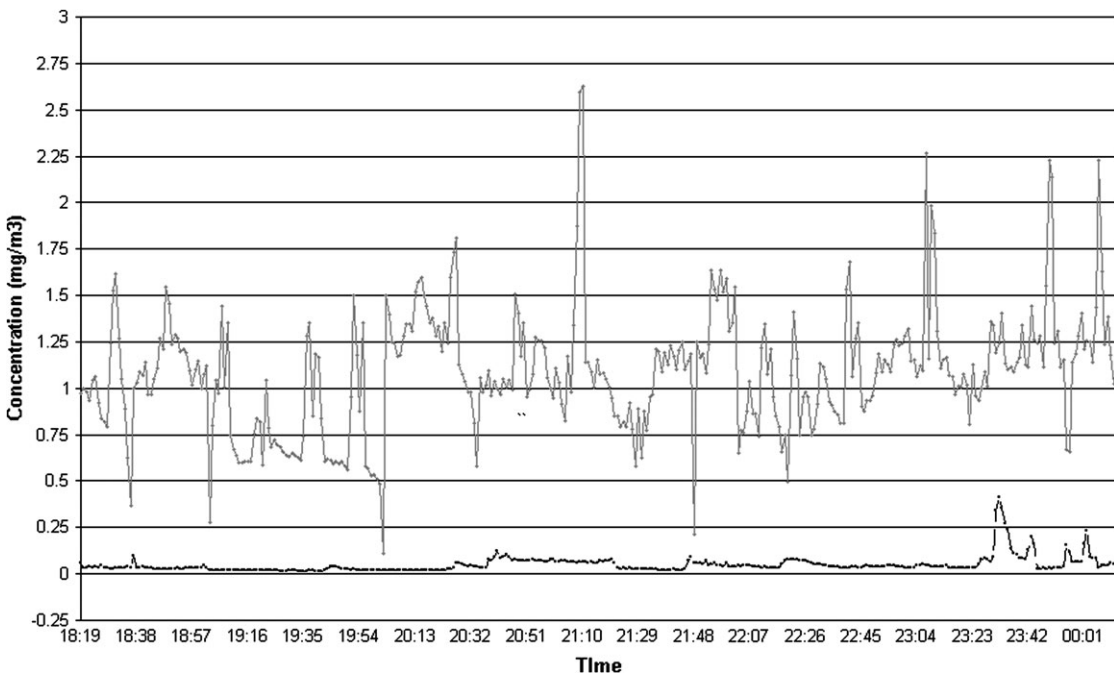


Fig. 2. Personal $PM_{2.5}$ exposure level measured for participant ID 4016 on two Friday night shifts in 2006. The upper line is the concentration measured pre-ban and the lower line the level measured post-ban. Note that the concentration of $PM_{2.5}$ is expressed in mg m^{-3} .

BHETSE cohort recruited from Aberdeen, Edinburgh and Glasgow but undeclared active smoking could have been responsible.

The reductions in cotinine levels in the BHETSE study resulted in confirmed non-smokers having a GM cotinine concentration of 0.41 ng ml^{-1} at Phase 3. This is very similar to the level of 0.38 ng ml^{-1} reported in a population survey ($n = 627$) of non-smokers in Scotland (S. Haw, L. Gruer, personal communication).

There were concerns that there would be a fall in compliance with the smoking restrictions over the colder, winter months of the first year. If anything our cotinine data seem to indicate that compliance increased from immediately post-ban to the 1-year follow-up stage. The cotinine level in non-smokers between Phase 2 and 3 showed a reduction of a further 45% (CI 27–61%) over and above the 78% (CI 71–84%) reduction seen in the first 2 months of the legislation between Phase 1 and 2. The self-report of the number of hours of exposure in the workplace within the past 7 days also suggested increasing compliance between May 2006 and February 2007, the AM duration of SHS exposure falling from 1.6 to 0.6 h between Phase 2 and 3. While the reductions in workplace SHS exposure among bar workers appeared to be large and sustained, there were clearly some bar workers who continued to be exposed at work. At Phase 2, some 21 of 260 (8.1%) reported still being exposed to SHS at work for >5 h in the past 7 days. By 1-year follow-up, this figure had reduced to only 6 of 184 respondents (3.3%) perhaps again indicating improving compliance though late 2006 into early 2007.

Smokers also demonstrated reductions in cotinine levels across the three surveys. There was a 17-ng ml^{-1} fall in the GM cotinine concentrations between baseline and 1-year follow-up which is likely to be due to the combined effect of reductions in SHS levels within their working environment and any changes in their personal active smoking behaviours. It seems reasonable to assume that smoking bar workers would have experienced a salivary cotinine reduction of ~ 2 to 3 ng ml^{-1} due to the removal of SHS exposure, similar to their non-smoking colleagues. The remaining reduction in smokers' levels may be due to changes in their cigarette consumption. Our data show that regular smokers were smoking 2.7 fewer cigarettes per day by Phase 3 compared to baseline, with occasional smokers consuming 1.4 fewer cigarettes per day. Etter *et al.* (2000) suggest an effect on salivary cotinine of 14 ng ml^{-1} per additional cigarette and the 26-ng ml^{-1} reduction in the arithmetic mean salivary cotinine level of smokers between Phase 1 and 3 is consistent with the reductions in cigarette consumption seen among our smoking bar workers. In general, bar workers who smoked therefore showed much larger cotinine reductions

from changes to their smoking behaviour than are likely to have arisen from changes to their workplace SHS exposure.

It should be noted however that changes in cotinine levels are linked to nicotine intake, whereas the respiratory effects of cigarette smoke exposure are related to the particle phase. The health effects of reduced exposure to tobacco smoke are unlikely to be linear—indeed evidence suggests that SHS exposure may lead to nearly as much cardiovascular risk as active smoking despite providing only a small fraction of the nicotine intake experienced during active smoking (Barnoya and Glantz, 2005). Additionally, in terms of toxicity, there is evidence that sidestream smoke is four to six times more toxic than mainstream smoke on a mass for mass basis (Schick and Glantz, 2005) and so the health benefits of reducing non-smokers' exposure to SHS may be considerably greater than those experienced by smokers who, although having greater reductions in salivary cotinine concentrations, continue to be exposed to large amounts of mainstream and sidestream smoke as a result of their own smoking behaviour.

Personal PM_{2.5} exposure data

The personal exposure data reported in this study show that, prior to the introduction of the legislation, bar workers were exposed to full-shift time-weighted average PM_{2.5} levels of between 27 and $1070 \mu\text{g m}^{-3}$ with a GM level of $202 \mu\text{g m}^{-3}$. While there is no Workplace Exposure Limit for cigarette smoke in the workplace, it is perhaps reasonable to consider these workplace PM_{2.5} concentrations in the context of the UK Air Quality Standards (COMEAP, 2007) for outdoor air as recommended by the Expert Panel on Air Quality Standards. This system of banding is based on the possible health effects of air pollution, and for PM, it uses PM₁₀ (particles $<10 \mu\text{m}$ in size) as an indicator of air quality. UK air quality bands for PM₁₀ are divided in to four levels: $<50 \mu\text{g m}^{-3}$ (low), $50\text{--}75 \mu\text{g m}^{-3}$ (moderate), $75\text{--}100 \mu\text{g m}^{-3}$ (high) and $>100 \mu\text{g m}^{-3}$ (very high). It is generally accepted that PM_{2.5} makes up $\sim 65\%$ of PM₁₀ by mass. It is reasonable to equate the PM₁₀ $> 100 \mu\text{g m}^{-3}$ (very high) banding to a PM_{2.5} level of $\sim 65 \mu\text{g m}^{-3}$. In the United States, the Environmental Protection Agency's (US-EPA) outdoor Air Quality Index for PM_{2.5} rates a level of $65 \mu\text{g m}^{-3}$ to be 'unhealthy' and a level of $250 \mu\text{g m}^{-3}$ to be hazardous to health. The World Health Organization currently has a guidance value for outdoor air PM_{2.5} levels not to exceed $25 \mu\text{g m}^{-3}$ averaged over 24 h. In comparing these values, it should be remembered that outdoor air health guidance is based on epidemiological data for PM that is primarily derived from vehicle and industrial emissions and not from PM whose main origin is cigarette smoke. Outdoor air quality guidance is also based on a 24-h average,

while the exposure data we present here is for a working shift of typically 8-h duration. However, both outdoor air $PM_{2.5}$ and SHS are primarily derived from combustion sources and both have been shown to be associated with cardiovascular and respiratory ill-health end points. In this context, the pre-legislation occupational exposures of bar workers to $PM_{2.5}$, as a marker for SHS, were on average over two times the maximum level that would be deemed by the UK air quality banding system to be 'very high' for outdoor PM_{10} exposures and by direct comparison with the US EPA $PM_{2.5}$ limit, the average bar worker's exposure to $PM_{2.5}$ was ~ 3 times that classified as 'unhealthy', with some bar workers having full-shift exposures of 16 times this unhealthy level.

Full-shift $PM_{2.5}$ exposures after introduction of the smoke-free legislation fell to a GM level of $28 \mu g m^{-3}$ —close to the level of $PM_{2.5}$ in outside ambient air and well within the US EPA $65 \mu g m^{-3}$ unhealthy cut point. The average reduction in the paired samples of the full-shift data was 86% which is very similar to the findings from our earlier area/short-term sampling ($n = 53$) in bars that showed a fall from a GM level of 167 to $16 \mu g m^{-3}$ after the ban (Semple *et al.*, 2007).

Strengths and weaknesses of our study

Only 45% of bars approached within our study areas agreed to take part. While most bar managers cited time pressure, it is possible that some degree of bias was introduced in that bars managed by people resistant to the legislation may have been less likely to cooperate with the study. It is possible that participating bars may have been more likely to enforce the legislation than those who refused to participate though we have no evidence to support this.

The BHETSE study is a longitudinal study of a cohort of bar workers. Employment in this sector has traditionally attracted a highly mobile and often transient group of workers who work, while travelling or are students earning income while at university or college. This poses difficulties in follow-up over periods longer than a few weeks. Our follow-up of 51% over a 1-year period reflects these difficulties but our demographic data on those participants seen at each phase suggest that the profile of those lost to follow-up did not differ substantially from continuing participants. Our initial recruitment at baseline of >370 bar workers was geared to allow for substantial loss among this mobile occupational group.

Our large sample size and wide geographical spread across Scotland is a particular strength of our study. Using three centres, we were able to cover three cities in Scotland together with two rural areas. Bars located in postcodes from all deprivation categories were visited and further analyses are required to examine if there are differences in exposure changes between these areas.

Our use of both biomarkers and airborne levels of SHS also strengthens our findings. The similarities in the reductions of non-smokers' salivary cotinine levels with the fall in airborne $PM_{2.5}$ concentrations serves to reinforce the source of the bar workers' exposure. Our saliva samples were collected at various times of the day in relation to the workers' shifts. During our visits, some bar workers were coming on shift, others nearing the end of their shift while others came in to the bar outside of their normal work hours in order to participate. A previous study of New Zealand workers in environments where smoking was unrestricted demonstrated a 1.0-ng ml^{-1} cross-shift increase in salivary cotinine levels among 32 non-smokers (Bates *et al.*, 2002). The collection of some of our samples at points earlier in the work shift is likely to have underestimated workers' exposure but as the timing of our visits to each bar was broadly similar across all three surveys we do not expect that this would have introduced any systematic bias in our estimates of change.

Future work

The BHETSE study aims to examine short- and medium-term changes in respiratory health among bar workers as a result of smoke-free legislation in Scotland. Some members of our group are also involved in studies looking at changes in occupational exposures to SHS resulting from the recent English smoke-free legislation and it will be interesting to note similarities and differences between the countries and determine if further improvements can be made. There is a particular need to determine what factors influence non-compliance, and to understand why some bar workers continue to be exposed to SHS. Research is also needed to more fully understand occupational exposures in workplaces that continue to be exempt under smoke-free legislation such as care homes, psychiatric hospitals and prisons. More generally, there is a need for those involved in occupational hygiene to learn from the policy and implementation measures to reduce SHS exposures in the workplace, driven mainly by the public health community, and to apply these to other areas where workers are exposed to hazardous chemicals.

Conclusions

The Smoking, Health and Social Care (Scotland) Act of 2005 was primarily introduced as a measure to protect the health of non-smokers who were exposed to SHS at work. As an occupational hygiene control measure, it has proved effective in reducing exposures to SHS among bar workers in Scotland. One year after implementation of the legislation non-smoking bar workers in Scotland now have biomarkers of SHS exposure comparable to those of the general population and have shown statistically significant and sustained falls in intensity and

duration of their exposure to SHS at work. Smokers have also shown reductions in exposure to tobacco smoke, in terms of both SHS and active consumption.

FUNDING

The BHETSE study was co-funded by NHS Health Scotland and the Scottish Executive Health Improvement Directorate.

Acknowledgements—We are extremely grateful to the bar staff and managers who took part in this study and to members of the BHETSE study Advisory Committee Group (Ms Sally Haw, Dr Colin Fischbacher, Professor David Hole and Dr Martie van Tongeren) for their help and contribution. We are also grateful to Mr Fintan Hurley for his comments on the manuscript.

REFERENCES

- Allwright S, Paul G, Greiner B *et al.* (2005) Legislation for smoke-free workplaces and health of bar workers in Ireland: before and after study. *BMJ*; 331: 1117–23.
- Barnoya J, Glantz S. (2005) Cardiovascular effects of secondhand smoke. *Circulation*; 111: 2684–98.
- Bates M, Fawcett J, Dickson S *et al.* (2002) Exposure of hospitality workers to environmental tobacco smoke. *Tob Control*; 11: 125–9.
- COMEAP. (2007) COMEAP statement on banding of air quality. Available at: <http://www.advisorybodies.doh.gov.uk/comeap/statementsreports/airpol9.htm>. Accessed 17 July 2007.
- Eisner M. (2005) Environmental tobacco smoke and adult asthma. *Exp Lung Res*; 31(Suppl. 1): 8–14.
- Eisner M, Smith A, Blanc P. (1998) Bartenders' respiratory health after establishment of smoke-free bars and taverns. *JAMA*; 280: 1909–14.
- Etter JF, Vu Duc T, Perneger TV. (2000) Saliva cotinine levels in smokers and nonsmokers. *Am J Epidemiol*; 151: 251–8.
- Feyerabend C, Russell M. (1990) A rapid gas-liquid chromatographic method for the determination of cotinine and nicotine in biological fluids. *J Pharm Pharmacol*; 42: 450–2.
- Goodman P, Agnew M, McCaffrey M *et al.* (2007) Effects of the Irish smoking ban on respiratory health of bar workers and air quality in Dublin pubs. *Am J Respir Crit Care Med*; 175: 840–5.
- Hackshaw A. (1997) The accumulated evidence on lung cancer and environmental tobacco smoke. *BMJ*; 315: 980–8.
- Haw S, Gruer L, Amos A *et al.* (2006) Legislation on smoking in enclosed public places in Scotland: how will we evaluate the impact? *J Public Health*; 28: 24–30.
- Hilton S, Semple S, Miller BG *et al.* (2007) Expectations and changing attitudes of bar workers before and after the implementation of smoke-free legislation in Scotland. *BMC Public Health*; 7: 206.
- Hole D. (2005) Passive smoking and associated causes of death in adults in Scotland. A report for the Scottish Executive. Edinburgh: NHS Health Scotland. Available at: <http://www.healthscotland.com/uploads/documents/MortalityStudy.pdf>. Accessed 7 August 2007.
- Howard J. (2004) Smoking is an occupational hazard. *Am J Ind Med*; 46: 161–9.
- Jaakkola M, Jaakkola J. (2006) Impact of smoke-free workplace legislation on exposures and health: possibilities for prevention. *Eur Respir J*; 28: 397–408.
- Jamrozik K. (2005) Estimate of deaths attributable to passive smoking among UK adults: database analysis. *BMJ*; 330: 812–24.
- Jarvis M. (2001) Quantitative survey of exposure to other people's smoke in London bar staff. A report for SmokeFree London 2001. (sflondon@doh.gsi.gov.uk).
- Law M, Morris J, Wald N. (1997) Environmental tobacco smoke exposure and ischaemic heart disease: an evaluation of the evidence. *BMJ*; 315: 973–80.
- Menzies D, Nair A, Williamson P *et al.* (2006) Respiratory symptoms, pulmonary function and markers of inflammation among bar workers before and after a legislative ban on smoking in public places. *JAMA*; 296: 1742–8.
- Mulcahy M, Evans D, Hammond S *et al.* (2005) Secondhand smoke exposure and risk following the Irish smoking ban: an assessment of salivary cotinine concentrations in hotel workers and air nicotine levels in bars. *Tob Control*; 14: 384–8.
- Otsuka R, Watanabe H, Hirata K *et al.* (2001) Acute effects of passive smoking on the coronary circulation in healthy young adults. *JAMA*; 286: 436–41.
- Repace J. (2006) Air pollution in Virginia's hospitality industry. Final report 2006. Available at: <http://www.repace.com/pdf/VAAQSurvey.pdf>. Accessed 15 July 2007.
- Schick S, Glantz S. (2005) Philip Morris toxicological experiments with fresh sidestream smoke: more toxic than mainstream smoke. *Tob Control*; 14: 396–404.
- Semple S, Creely K, Naji A *et al.* (2007) Secondhand smoke levels in Scottish pubs: the effect of smoke-free legislation. *Tob Control*; 16: 127–32.
- The Scottish Executive. (2005) Scotland's people: results from the 2003 Scottish household survey: annual report. [Online] Available at: <http://www.scotland.gov.uk/Publications/2005/11/25145024/50251>. Accessed 14 July 2007.
- The Scottish Executive. (2006) Scotland's people: results from the 2005 Scottish household survey: annual report. [Online] Available at: <http://www.scotland.gov.uk/Resource/Doc/140387/0034518.pdf>. Accessed 17 July 2007.
- The Scottish Executive. (2007) Scotland's people: headline results from the 2006 Scottish household survey: annual report. [Online] Available at: <http://www.scotland.gov.uk/Publications/2007/06/04150044/0>. Accessed 17 July 2007.