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RESEARCH

Changes in exposure of adult non-smokers to secondhand smoke after implementation of smoke-free legislation in Scotland: national cross sectional survey

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ABSTRACT

Objective To measure change in adult non-smokers' exposure to secondhand smoke in public and private places after smoke-free legislation was implemented in Scotland.

Design Repeat cross sectional survey.

Setting Scotland.

Participants Scottish adults, aged 18 to 74 years, recruited and interviewed in their homes.

Intervention Comprehensive smoke-free legislation that prohibits smoking in virtually all enclosed public places and workplaces, including bars, restaurants, and cafes.

Outcome measures Salivary cotinine, self reported exposure to smoke in public and private places, and self reported smoking restriction in homes and in cars.

Results Overall, geometric mean cotinine concentrations in adult non-smokers fell by 39% (95% confidence interval 29% to 47%), from 0.43 ng/ml at baseline to 0.26 ng/ml after legislation (P<0.001). In non-smokers from non-smoking households, geometric mean cotinine concentrations fell by 49% (40% to 56%), from 0.35 ng/ml to 0.18 ng/ml (P<0.001). The 16% fall in cotinine concentrations in non-smokers from smoking households was not statistically significant. Reduction in exposure to secondhand smoke was associated with a reduction after legislation in reported exposure to secondhand smoke in public places (pubs, other workplaces, and public transport) but not in homes and cars. We found no evidence of displacement of smoking from public places into the home.

Conclusions Implementation of Scotland's smoke-free legislation has been accompanied within one year by a large reduction in exposure to secondhand smoke, which has been greatest in non-smokers living in non-smoking households. Non-smokers living in smoking households continue to have high levels of exposure to secondhand smoke.

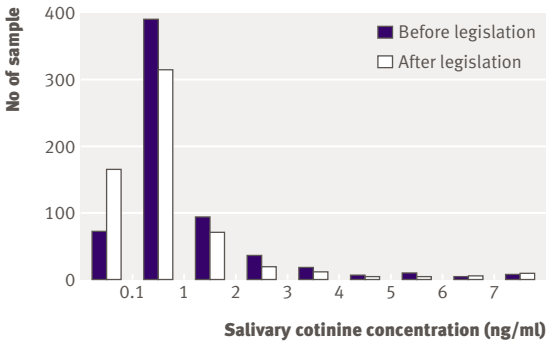
INTRODUCTION

Exposure to secondhand smoke has a causal association with the development of lung cancer, coronary heart disease, respiratory disease, and stroke in adult non-smokers.[1-4] A recent review concluded that there is evidence of a causal association between secondhand exposure to smoke and nasal sinus cancer; breast cancer in younger, primarily premenopausal women; and asthma induction and exacerbation in adults.[5] Based on the four main diseases related to secondhand smoke, each year an estimated 79 000 adult non-smokers die in European Union countries,[6] 11 317 in the entire United Kingdom,[7] and 865 in Scotland[8] from secondhand exposure to smoke in private and public places. Most (80%) deaths in the UK occur as a result of exposure in private places.[7] However, taking into account an increasing proportion of non-smokers in the population—which will increase the proportion who are susceptible to the health effects of secondhand smoke over time—implementation of legislation that prohibited smoking in enclosed public places in Scotland could ultimately save up to 400 lives every year, with the full health benefits taking around 20 years to accrue.[9]

Even occasional exposure to secondhand smoke is associated with cardiovascular changes, including increased platelet aggregation, endothelial dysfunction, and arterial stiffening.[10] Heart rate variability is reduced after only two hours' exposure, potentially increasing the risk of acute myocardial infarction.[11] These immediate effects on the cardiovascular system provide a plausible explanation for the observed reductions in hospital admissions for acute myocardial infarction in areas in the United States and Italy after implementation of smoke-free legislation.[12-14]

On 26 March 2006 comprehensive legislation was implemented in Scotland to prohibit smoking in virtually all enclosed public places and workplaces, including bars, restaurants, and cafes. The limited number of exemptions include residential accommodation and designated rooms in hotels, care homes, hospices, and psychiatric units.[15] The main aim of the legislation is to eliminate exposure to secondhand smoke in public places, thereby contributing to improving the health of the Scottish population.

A study of air quality in a random sample of 41 pubs in urban and rural Scotland has reported an overall 86% reduction in small airborne particles ($PM_{2.5}$)—an air marker of secondhand smoke—two months after implementation of the legislation.[16] These data are consistent with studies from other countries where similar legislation has been introduced,[17 18] but the



Cotinine concentrations in non-smokers before and after smoke-free legislation in Scotland

generalisability of these results to all enclosed public places covered by the legislation is not known, nor is the likely impact any reductions will have on overall levels of exposure to secondhand smoke in the general population.

This study is part of a comprehensive evaluation of Scotland's smoke-free legislation.[19] It aimed to determine if a measurable change occurred in secondhand smoke exposure in adult non-smokers after implementation of the Scottish smoke-free legislation; to assess whether overall changes in secondhand exposure were related to exposure in public or private spaces; and to determine if any evidence existed of increased exposure to secondhand smoke among non-smokers living with smokers, associated with displacement of smoking into the home.

METHODS

Survey

Data on adult exposure to secondhand smoke were collected as part of the health education population survey, using a repeat cross sectional design before and after implementation of the legislation. This survey is a cross sectional in-home survey of adults living on mainland Scotland that has been conducted in most years since 1996 to monitor health related knowledge and behaviour.[20] Data are collected twice a year in two waves. For this study, survey waves conducted between 1 September and 20 November 2005 and between 9 January and 25 March 2006 provided baseline data. Post-legislation data were collected in two waves between 1 September and 10 December 2006 and between 8 January and 2 April 2007.

Sampling strategy

Addresses from mainland Scotland were selected from the Royal Mail postcode address file using a rolling, multistage, clustered random sampling strategy. Postcode sectors were first stratified by the Carstairs deprivation index (an area based socioeconomic measure, rainging from 1 (most affluent) to 7 (most deprived) [21]) within each of the 14 administrative areas of the NHS in Scotland. For collection of baseline data, households were sampled in 72 postcode sectors. In the first wave of post-legislation sampling, an additional six sectors were added during fieldwork to adjust for a higher than expected proportion of addresses that no longer existed or were of ineligible households (with no adults aged 16-74 years). Sectors were selected with a probability proportional to the total number of addresses in that sector.

Half of the sampling points in the first pre-legislation wave (A sectors) had been used in the preceding survey wave of the health education population survey. The remaining sampling points in the first wave (B sectors) were then drawn from the postal address file. For the second pre-legislation wave, the A sectors were dropped and the B sectors used again, with the remaining sampling points (C sectors) drawn afresh. This process was continued for the post-legislation sampling, creating an interlocking sample across the four waves. Within each postcode sector, one address was selected at random and the remaining households drawn with a sampling interval of 20 households, until 22 households per sector (23 in the fourth wave) were selected. When postcode sectors were used for a second time, the same sampling interval was used but with a different starting point.

One week before the start of fieldwork, a letter was sent to all selected addresses informing the occupier that the household had been chosen to take part in the survey. The letter explained that the purpose of the survey was to collect data on "Scottish people's views on health" and householders were notified that an interviewer would be calling on them in the near future. On contact with potential study participants, interviewers confirmed that they were "carrying out a survey about the health of Scottish people for NHS Health Scotland."

Selection of study participants

People aged 16 to 74 years were eligible to participate in the study. In households with more than one eligible adult, the individual with the most recent birthday was selected. No substitutes were accepted. Interviewers made a minimum of five visits to obtain an interview.

Interviews

Study participants were interviewed at home by trained interviewers. Data on a range of health behaviours were collected by using computer assisted personal interviewing. The smoking module included self reported smoking status, date of cessation, and use of nicotine replacement therapy. Data were collected on the participants' experience of smoking restrictions in public places (work, pubs, and public transport) and private places (home and car) and on reported exposure to secondhand smoke in these different locations. The questionnaire is available at www.healthscotland.com/scotlands-health/evaluation/policy-evaluation/smoking.aspx. After completing the questionnaire, all respondents were asked to provide a sample of saliva. It was explained that the samples would be used to measure change in "exposure to cigarette smoke in

the Scottish population before and after the (smoking) ban."

Cotinine

Cotinine, a metabolite of nicotine, is present in body fluids—blood, saliva, and urine—and is a stable and highly specific and sensitive biomarker of both active and passive absorption of tobacco smoke.[22] Unstimulated samples of saliva were collected by placing a sterile salivette (cotton wool roll) in the mouth for three minutes without chewing until it was wet with saliva. Samples were stored in individual containers at 3°C until sent to the testing laboratory, where they were stored at −20°C until testing.

Saliva samples were analysed by using gas chromatography with a specific nitrogen/phosphorus detector.[23] Cotinine and the internal standard 5-methyl cotinine were extracted using dichloroethane from a 100 µl sample after alkalisation using sodium hydroxide. The lower limit of detection was 0.1 ng/ml.

Definition of smoking status and the assessment of outcomes

We based assessment of change in exposure to secondhand smoke in non-smokers on self reported non-smoking status (never smoker or ex-smoker), confirmed by salivary cotinine concentration. Respondents who were using nicotine replacement therapy were excluded from the analysis, as were "smoking deceivers," who were defined as respondents who reported that they were non-smokers but had a cotinine concentration above 15 ng/ml, the accepted threshold for active smoking.[24] Assessments of changes in location of exposure to secondhand smoke and smoking restriction in homes and cars in non-smokers are based on self reported smoking status alone.

Table 1 | Profiles of samples of non-smokers recruited before and after implementation of legislation prohibiting smoking in enclosed public places. Values are numbers (percentages)

Characteristic	All non-smokers			Non-smokers with valid cotinine‡		
	Before legislation*	After legislation*	P value	Before legislation*	After legislation*	P value
Sex:	(n=1169)	(n=1190)		(n=627)	(n=593)	
Male	547 (46.8)	560 (47.1)	>0.05	301 (48.0)	303 (51.1)	>0.05
Female	622 (53.2)	630 (52.9)		326 (52.0)	290 (48.9)	
Age (years):	(n=1168)	(n=1191)		(n=626)	(n=592)	
16-24	163 (14.0)	196 (16.5)		93 (14.9)	101 (17.1)	
25-34	222 (19.0)	239 (20.1)		129 (20.6)	113 (19.1)	
35-44	236 (20.2)	200 (16.8)	>0.05	123 (19.6)	115 (19.4)	>0.05
45-54	219 (18.8)	214 (18.0)		114 (18.2)	104 (17.6)	
55-64	163 (14.0)	185 (15.5)		81 (12.9)	93 (15.7)	
65-74	165 (14.1)	157 (13.2)		86 (13.7)	66 (11.1)	
Marital status:	(n=1169)	(n=1185)		(n=627)	(n=588)	
Single	271 (23.2)	329 (27.8)	<0.05†	154 (24.6)	175 (29.8)	>0.05
Married or cohabiting	757 (64.8)	751 (63.4)		415 (66.2)	367 (62.4)	
Separated or divorced	141 (12.1)	105 (8.9)		58 (9.3)	46 (7.8)	
Education (years):	(n=1169)	(n=1190)		(n=627)	(n=592)	
≤11	620 (53.0)	566 (47.6)	<0.01†	301 (48.0)	264 (44.6)	>0.05
>11	549 (47.0)	624 (52.4)		326 (52.0)	328 (55.4)	
Deprivation category:	(n=1164)	(n=1190)		(n=627)	(n=592)	
1 (most affluent)	115 (9.9)	154 (12.9)		47 (7.5)	75 (12.7)	
2	203 (17.4)	195 (16.4)		133 (21.2)	105 (17.7)	
3	245 (21.0)	267 (22.4)	<0.05†	122 (19.5)	151 (25.5)	<0.001†
4	248 (21.3)	277 (23.3)		142 (22.6)	124 (20.9)	
5	188 (16.2)	167 (14.0)		101 (16.1)	90 (15.2)	
6	122 (10.5)	104 (8.7)		60 (9.6)	32 (5.4)	
7 (most deprived)	43 (3.7)	26 (2.2)		22 (3.5)	15 (2.5)	
Smoking status:	(n=1170)	(n=1190)		(n=627)	(n=593)	
Ex-smoker	444 (37.9)	409 (34.4)	>0.05	220 (35.1)	223 (37.6)	>0.05
Never smoker	726 (62.1)	781 (65.6)		407 (64.9)	370 (62.4)	
Salivary cotinine:	(n=1169)	(n=1190)				
Sample collected	758 (64.8)	751 (63.1)	>0.05	—	—	—
Cotinine value	655 (56.0)	609 (51.2)		—	—	
Valid cotinine value‡	627 (53.6)	592 (49.7)		627 (100)	529 (100)	

Data analysis

All data were analysed in SPSS version 15, using non-parametric tests, analysis of covariance (ANCOVA), and binary logistic and ordinal logistic regression analyses. Data in all analyses were weighted to correct for multiple occupancy, size of household, sex, and age. Cotinine values were subjected to logarithmic transformation to counter skew, with samples below the limit of detection assigned a value of 0.5 ng/ml (half the limit of detection value) before transformation.

RESULTS

Sample

The response rates in the four successive waves—70%, 71%, 66%, and 71%—compare well with other UK national surveys, which have response rates of around 66%.[25 26] A total of 1815 participants were recruited to the baseline survey and 1834 to the post-legislation survey. The profiles of the weighted samples were similar in sex, age, marital status, and smoking status. However, respondents in the post-legislation sample were more likely to have more than 11 years' education ($P<0.01$) and less likely to live in the most deprived areas (Carstairs deprivation categories 5 to 7) ($P<0.001$).

The prevalence of smoking (cigarettes, pipes, or cigars) was 35.6% (646/1815) in the pre-legislation sample and 35.1% (644/1834) in the post-legislation sample. Exclusion of smokers yielded final sample sizes of 1170 before legislation and 1190 after legislation. The two samples were similar in sex, age, marital status, years in education, and previous smoking history, but the non-smokers recruited after implementation of the legislation were less likely to live in areas in the most deprived Carstairs deprivation categories ($P<0.001$) (table 1).

Provision of saliva sample for testing for cotinine

In total, 758 (64.8%) of 1170 self reported non-smokers agreed to provide a sample of saliva at baseline and 751 (63.1%) of 1190 self reported non-smokers recruited after legislation agreed. Subsequently 655 respondents (55.9%) before legislation and 609 (51.1%) after legislation provided an uncontaminated sample of sufficient volume for cotinine measurement. Excluding non-smokers who were taking nicotine replacement therapy and smoking deceivers resulted in valid cotinine measurements for 627 (53.6%) baseline respondents and 592 (49.7%) respondents recruited after the legislation. Compared with those who did not, respondents who had a valid cotinine measurement were more likely to be male (50.5% *v* 49.5%; $P<0.05$) and have 11 or more years of education (53.7%% *v* 45.6%; $P<0.001$). They were also less likely to be 55 years or older (26.8% *v* 30.2%; $P<0.01$) and to live in areas in Carstairs deprivation category 6 and 7 (10.6% *v* 14.6%; $P=0.001$). Table 1 compares the profile of respondents who provided valid cotinine measurements before and after the legislation. Respondents recruited before and after legislation were similar in sex, age, marital status, years in education, and previous smoking history, but post-legislation respondents with a valid cotinine measurement were less likely to live in areas with higher deprivation indices ($P<0.001$).

Changes in exposures to secondhand smoke in adult non-smokers

Cotinine measurements for 627 non-smokers recruited pre-legislation and 592 non-smokers recruited post-legislation were analysed to assess change in exposure to secondhand smoke. Before legislation the median and mode values were 0.4 ng/ml and 0.3 ng/ml respectively, with a range of <0.1 ng/ml (below the level of detection) to 10.5 ng/ml. After legislation the range was wider (<0.1 ng/ml to 13.7 ng/ml) but the median fell to 0.2 ng/ml and the mode to <0.1 ng/ml. The distribution of cotinine values shifted (figure), with an increase in the proportion of samples below the level of detection (0.1 ng/ml), from 11.3% (71 samples) before legislation to 27.6% (165) afterwards (figure).

The impact of the smoke-free legislation on exposure to secondhand smoke (log cotinine) was evaluated using analysis of covariance. Two independent variables (smoking ban and household smoking status (non-smoking household *v* households with at least one smoker)) and three covariates (sex, years in education, and deprivation category of residence) were included in the model.

Table 2 compares geometric mean cotinine values before and after legislation, with the covariates controlled for. The overall geometric mean cotinine for non-smokers fell from 0.43 ng/ml at baseline to 0.26

Table 2 | Mean cotinine concentrations in non-smokers before and after implementation of legislation prohibiting smoking in enclosed public places

No of smokers in household	Before legislation		After legislation		Adjusted reduction in mean cotinine†	
	No	Mean (95% CI)*	No	Mean (95% CI)*	% (95% CI)	P value
None	504	0.35 (0.32 to 0.39)	449	0.18 (0.16 to 0.20)	49 (40 to 56)	‹0.001
One or more	123	0.92(0.74 to 1.13)	143	0.81 (0.67 to 0.99)	16 (−11 to 37)	›0.05
All	627	0.43 (0.39 to 0.47)	592	0.26 (0.23 to 0.29)	39 (29 to 47)	‹0.001

*Geometric mean cotinine concentrations in ng/ml, controlling for sex, years in education, and deprivation category of residence.
†Adjusted percentage reduction in geometric mean cotinine concentrations in ng/ml, controlling for sex, years in education, and deprivation category of residence.

ng/ml after legislation. This represents a 39% adjusted reduction in mean cotinine after implementation of the legislation (P<0.001). The interaction between implementation of legislation and household smoking status was highly significant. The geometric mean cotinine for non-smokers living in non-smoking or smoking households fell from 0.35 ng/ml to 0.18 ng/ml, representing a 49% adjusted reduction in mean cotinine in this group (P<0.001). For non-smokers living in smoking households it fell by only 16% (from 0.92 ng/ml to 0.81 ng/ml) and did not reach statistical significance.

Before the legislation, non-smokers living in smoking households had levels of exposure to secondhand smoke on average 2.6 times higher than those of non-smokers living in non-smoking households. After the legislation, levels of exposure to secondhand smoke in non-smokers living in smoking households were on average 4.5 times higher.

Reported exposure to secondhand smoke in public and private

All non-smokers participating in the study were asked in which of six private and public locations they were exposed to secondhand smoke in the seven days before the interview, and logistic regression was used to assess the likelihood of being exposed to secondhand smoke in these different locations (table 3). The proportion of respondents reporting exposure to secondhand smoke fell for all locations after the legislation, but after controlling for sex, years in education and deprivation category of residence were controlled for, reported exposure to secondhand smoke was significantly reduced only in enclosed public places covered by the legislation: in pubs (odds ratio 0.03 (95% confidence interval 0.02 to 0.05; P<0.001); at work (0.32 (0.23 to 0.45); P<0.001); on public transport (0.29 (0.15 to 0.57); P<0.001), and in other enclosed public places (0.25 (0.17 to 0.38); P<0.001). The likelihood of exposure in private enclosed places—own home, others' home or car—did not change significantly.

Reported smoking restriction in private enclosed places

Respondents were asked about smoking restrictions in their homes and cars, and we assessed the relation between smoking restrictions and smoking status and implementation of legislation by using ordinal regression. Table 4 compares the smoking restrictions in place in the homes and cars of the two groups of non-smokers before and after legislation After sex, deprivation category of residence, and years of education were controlled for, post-legislation, non-smokers were more likely to report having either a complete smoking ban or a partial ban, irrespective of household smoking status (1.49 (1.26 to 1.76); P<0.001). .

In total, 80.8% (943) of non-smokers recruited before legislation lived in a car owning household, compared with 83.7% (996) after legislation. Complete smoking bans in cars were more common than in homes and were more common for non-smokers from non-smoking households than those from smoking households. However, after sex, deprivation category of residence, and years of education were controlled for, no change in the pattern of reported smoking restrictions in cars was observed after implementation of the legislation either overall (0.86, 0.65 to 1.13) or within the two non-smoker subgroups.

Table 3 | Impact of smoke-free legislation on places where non-smokers reported exposure to secondhand smoke

Where exposed to secondhand smoke	No (%) of non-smokers exposed	Odds ratio (95% CI)*	P value
Own home:			
Before legislation	203/1169 (17.4)	1.05 (0.84 to 1.30)	>0.05
After legislation	203/1190 (17.1)		
Others' home:			
Before legislation	249/1169 (21.3)	0.97 (0.79 to 1.18)	>0.05
After legislation	247/1190 (20.8)		
Car:			
Before legislation	95/1169 (8.1)	0.81 (0.59 to 1.11)	>0.05
After legislation	81/1190 (6.8)		
Work:			
Before legislation	145/1169 (12.4)	0.32 (0.23 to 0.45)	<0.001
After legislation	51/1190 (4.3)		
Pub or bar:			
Before legislation	386/1169 (33.0)	0.03 (0.02 to 0.05)	<0.001
After legislation	20/1190 (1.7)		
Public transport:			
Before legislation	38/1169 (3.3)	0.29 (0.15 to 0.57)	<0.001
After legislation	11/1190 (0.9)		
Other enclosed places:			
Before legislation	110/1169 (9.4)	0.25 (0.17 to 0.38)	<0.001
After legislation	31/1190 (2.6)		

*Binary logistic regression analyses controlling for sex, years of education, and deprivation category of residence.

DISCUSSION

Main findings

This study provides evidence of a large reduction in secondhand smoke exposure in non-smoking adults in Scotland after implementation of legislation banning smoking in enclosed public spaces. The geometric mean salivary cotinine concentrations in adult non-smokers fell from 0.47 ng/ml at baseline to 0.26 ng/ml after the legislation, representing a 39% reduction in exposure to secondhand smoke. The greatest reduction in exposure to secondhand smoke occurred in non-smokers living in non-smoking households, who had a 49% reduction in mean salivary cotinine concentration after the legislation. Non-smokers living in smoking households showed a reduction of 16%, which was not statistically significant. The reduction in secondhand smoke exposure after implementation of the legislation was associated with a reduction in reported exposure to secondhand smoke in public places (pubs, other workplaces, and public transport) but not in private places (homes and cars).

Although objective measures of exposure to secondhand smoke in non-smokers living in smoking households did not fall significantly after the legislation, there was no evidence of an increase in exposure to secondhand smoke in respondents' own homes, other people's homes, or in cars. Indeed, although non-smokers from smoking households were less likely than those from non-smoking households to restrict smoking in private places—either in homes or in cars—after the legislation the proportion reporting stricter home smoking restrictions increased in both groups. Taking this and our cotinine data on exposure to secondhand smoke into account, we conclude that there is no evidence of displacement of smoking into the home after implementation of Scotland's smoke-free legislation.

Strengths and weaknesses of the study

The study recruited representative samples of the Scottish population and had response rates exceeding those of other recent UK national household surveys. Both self reported and biovalidated markers of smoking status and exposure to secondhand smoke were collected. The baseline and post-legislation data were collected in the same period of the year, exactly one year apart. This increases the likelihood that the observed differences before and after legislation are due to the intervention rather than to secular changes associated with other tobacco control interventions or systematic bias associated with seasonal differences between the times when the data were collected.

Our repeat cross sectional design is less robust than a longitudinal design. However, loss to follow-up in longitudinal surveys, particularly in younger age groups, can be considerable, thus eliminating or reducing any benefits of using this study design. The samples recruited before and after legislation showed some small socioeconomic differences but these differences were controlled for in the analyses, making systematic bias unlikely. The compliance rates for provision of saliva sample for testing for cotinine were disappointing but similar to rates achieved by other UK surveys.[26] There were small socioeconomic differences between respondents who agreed and those who refused to provide saliva samples, but these were controlled for in the analyses, making systematic bias unlikely. It was not feasible to include a control group from outside Scotland. However, the findings from this study will be integrated with findings from six other studies and analyses of routine health and behavioural datasets, which make up the national evaluation of the Scottish smoke-free legislation.[18]

Other studies

The national health and nutrition examination survey (NHANES), which used serum cotinine concentrations to estimate secondhand smoke exposure in the United States, found that between 1988 and 2000 median cotinine concentrations declined by more than 70% in adult non-smokers.[27] A 52% drop in mean salivary

Table 4 | Impact of smoke-free legislation on smoking restrictions in homes and cars of non-smokers. Values are numbers (percentages)

	Non-smokers in non-smoking homes		Non-smokers in smoking homes		All non-smokers	
Smoking restrictions	Before legislation	After legislation	Before legislation	After legislation	Before legislation	After legislation
Home:	(n=924)	(n=913)	(n=243)	(n=276)	(n=1167)	(n=1189)
Complete ban	541 (58.5)	628 (68.8)	66 (27.2)	91 (33.0)	607 (52.0)	719 (60.5)
Partial ban	315 (34.1)	237 (26.0)	99 (40.7)	126 (45.7)	414 (35.5)	363 (30.5)
No restrictions	68 (7.4)	48 (5.3)	78 (32.7)	59 (21.4)	146 (12.5)	107 (9.0)
Odds ratio (95% CI)*					1.49 (1.26 to 1.76); P<0.001	
Car:†	(n=773)	(n=772)	(n=190)	(n=224)	(n=943)	(n=996)
Complete ban	710 (91.8)	713 (92.4)	133 (70.0)	138 (61.6)	823 (85.5)	851 (85.4)
Partial ban	44 (5.7)	44 (5.7)	25 (13.2)	50 (22.3)	69 (7.2)	94 (9.4)
No restrictions	19 (2.5)	15 (1.9)	32 (16.8)	36 (16.1)	51 (5.3)	51 (5.1)
Odds ratio (95% CI)*					0.86 (0.65 to 1.13); P>0.05	

*Odds ratios for adjacent categories as estimated from ordinal logistic regression controlling for sex, years in education, and deprivation category of residence.
†Respondents living in car owning households.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Exposure to secondhand smoke is associated with considerable morbidity and mortality in non-smokers

Smoking bans have been shown to be effective in reducing exposure to secondhand smoke in some locations

WHAT THIS STUDY ADDS

Legislation to prohibit smoking in public places resulted in a large reduction in adults non-smokers' exposure to secondhand smoke across a whole population

After implementation of the legislation, exposure to secondhand smoke was reduced in all public places and workplaces but not in the home or private cars

The main beneficiaries of the legislation seem to be non-smokers living in non-smoking homes

The legislation did not result in increased exposure to secondhand smoke in the homes of non-smokers who lived with other smokers

cotinine was seen in English schoolchildren between 1988 and 2003.[28] These data indicate a gradual reduction in exposure to secondhand smoke in both countries. The changes are probably associated with tobacco control strategies that have been implemented in the past decade, including prevention and education campaigns on the health risks associated with both active and passive smoking and the development of smoking cessation services for smokers, as well as smoke-free legislation.[27] However, the 39% reduction in mean cotinine concentrations in Scottish adults in our study has occurred in only one year. Most if not all of this reduction is likely to be due to the implementation of the Scottish smoke-free legislation. This strongly suggests that the legislation has rapidly reduced secondhand smoke exposure at a population level.

The 86% improvement in air quality in 41 Scottish pubs already reported indicates that at two months after legislation there were very high levels of compliance with the legislation in pubs.[16] Our data on locations of secondhand smoke exposure indicate that there has been high compliance in all public places covered by the legislation for up to one year after legislation. Similar improvements in air quality in bars and workplaces, as well as reductions in self reported exposure to secondhand smoke in public places, have been reported from elsewhere after implementation of smoke-free legislation.[17 29 30] Our data are consistent with and reinforce findings from a four country study that failed to find evidence of displacement of smoking from public places into the home but found that smoke-free legislation stimulated the adoption of smoke-free homes.[31]

Our findings are also almost identical to those of a parallel study of secondhand smoke exposure in Scottish schoolchildren, which also found an overall reduction of 39% in geometric mean cotinine concentrations after the legislation. The reduction reached statistical significance only among children living in non-smoking households and in households where only the father figure smoked.[32]

Implications

There is good evidence that long term secondhand smoke exposure is harmful to respiratory and cardiovascular health.[1-3] Implementation of smoke-free legislation in other countries has been associated with a rapid improvement in reported respiratory and sensory symptoms and lung function of bar workers,[33 34] who as a group have high levels of exposure in the workplace. Evidence is growing that even occasional exposure to secondhand smoke can have important and immediate cardiovascular effects that increase the risk of acute myocardial infarction.[10 11] This suggests that the reductions in exposure to secondhand smoke of the order observed in Scotland may generate immediate health gains in the Scottish population as well as longer term reductions in morbidity and mortality related to secondhand smoke. However, to our knowledge, no data are yet available to relate a reduction of this magnitude in mean cotinine concentrations in adult non-smokers to actual improvements in health at a population level. Furthermore, our study indicates that, to date, a significant reduction in exposure to secondhand smoke occurred only in non-smokers living in non-smoking households. Indeed, the difference in mean cotinine concentrations between non-smokers living in smoking and non-smoking households almost doubled after implementation of the legislation.

The now large differential in exposure to secondhand smoke between non-smokers who live in smoking households and non-smoking households underlines the importance of developing interventions designed to reduce smoking in the home and in cars. Without further action on smoking in the home, health gains associated with the reduction in exposure to secondhand smoke that has been observed in Scotland are likely to accrue only to non-smokers living in non-smoking households.

Legislation on smoking in private homes is unlikely to be effective, acceptable, or desirable, although there may be more public acceptance of restrictions on smoking in cars, especially when children are being transported.[35] More could also be done to raise awareness of the health risks to both adults and children associated with exposure to secondhand smoke. In particular, the finding that non-smokers exposed to low levels of tobacco smoke relative to active smokers are still at heightened risk of coronary heart disease needs to be communicated clearly.[36]

Quitting smoking is probably the most effective way of reducing secondhand smoke exposure in the home; thus, with legislation in place, smoking cessation services must continue to be promoted both nationally and at a local level, with clear links made to the potential improvements in the health of non-smokers. Further work is needed to determine the most effective way of promoting smoke-free homes and cars among smokers who are unable to quit.

Conclusions

Our study has shown that Scotland's comprehensive smoke-free legislation has achieved its primary

objective—reducing secondhand smoke exposure in adult non-smokers. The reduction in secondhand smoke exposure was greatest in non-smokers living in non-smoking households—so any corresponding health gains are likely to be greatest in this group. Non-smokers living in smoking households continue to have high levels of secondhand exposure linked to exposure in the home. Further action is needed to support smoking households to implement smoke-free homes and cars.

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