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Changes in child exposure to environmental tobacco smoke (CHETS) study after implementation of smoke-free legislation in Scotland: national cross sectional survey

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ABSTRACT

Objective To detect any change in exposure to secondhand smoke among primary schoolchildren after implementation of smoke-free legislation in Scotland in March 2006.

Design Comparison of nationally representative, cross sectional, class based surveys carried out in the same schools before and after legislation.

Setting Scotland.

Participants 2559 primary schoolchildren (primary 7; mean age 11.4 years) surveyed in January 2006 (before smoke-free legislation) and 2424 in January 2007 (after legislation).

Outcome measures Salivary cotinine concentrations, reports of parental smoking, and exposure to tobacco smoke in public and private places before and after legislation.

Results The geometric mean salivary cotinine concentration in non-smoking children fell from 0.36 (95% confidence interval 0.32 to 0.40) ng/ml to 0.22 (0.19 to 0.25) ng/ml after the introduction of smoke-free legislation in Scotland—a 39% reduction. The extent of the fall in cotinine concentration varied according to the number of parent figures in the home who smoked but was statistically significant only among pupils living in households in which neither parent figure smoked (51% fall, from 0.14 (0.13 to 0.16) ng/ml to 0.07 (0.06 to 0.08) ng/ml) and among pupils living in households in which only the father figure smoked (44% fall, from 0.57 (0.47 to 0.70) ng/ml to 0.32 (0.25 to 0.42) ng/ml). Little change occurred in reported exposure to secondhand smoke in pupils' own homes or in cars, but a small decrease in exposure in other people's homes was reported. Pupils reported lower exposure in cafes and restaurants and in public transport after legislation.

Conclusions The Scottish smoke-free legislation has reduced exposure to secondhand smoke among young people in Scotland, particularly among groups with lower exposure in the home. We found no evidence of increased secondhand smoke exposure in young people associated with displacement of parental smoking into the home. The Scottish smoke-free legislation has thus had a positive short term impact on young people's health, but further efforts are needed to promote both smoke-free homes and smoking cessation.

INTRODUCTION

The main source of exposure to secondhand smoke among children is domestic, usually in the home or the car^{1,2}; the levels of exposure correlate with the prevalence of parental smoking.^{3,4} In the home, protection can arise only from voluntary family based restrictions by adults. Children can also be exposed in other contexts, including public places,² yet this is a little studied area.

On 26 March 2006 Scotland introduced legislation that prohibited smoking in most enclosed public places.^{5,6} Studies using objective measures have found that smoke-free legislation is an effective strategy for reducing secondhand smoke exposure in adults.⁷⁻⁹ However, an unintended consequence of smoke-free legislation might be displacement of adult smoking from public places into the home,^{10,11} thus increasing exposure to secondhand smoke among children living with adults who smoke. Evidence from elsewhere, however, does not support this supposition, as smoke-free legislation has been shown to be associated with an increase in smoke-free homes, a tendency to smoke less, and more successful cessation attempts among adults.¹²⁻¹⁴

Here we report results from the changes in child exposure to environmental tobacco smoke (CHETS) study. We examined the impact of the smoke-free legislation on children's exposure to secondhand smoke at a population level. In addition, we examined whether any evidence exists for increased parental smoking in the home associated with implementation of the Scottish smoke-free legislation.

METHODS

The CHETS study has a repeat cross sectional design. Two nationally representative class based surveys of children in their final year of primary school in Scotland were done in the same schools one year apart, before (January 2006) and after (January 2007) smoke-free legislation. All primary schools on mainland Scotland were included in the sample frame.

We asked each participating school to select one primary 7 class to take part. Researchers administered the survey in the classroom. Pupils completed a questionnaire that included questions on their own smoking

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status and that of their friends and parent figures and recent exposure to tobacco smoke in public and private locations. Children were also asked to provide a saliva sample for testing for cotinine, a major metabolite of nicotine and a sensitive indicator of the absorption of smoke products.¹⁵ We excluded pupils who had cotinine concentrations above 15 ng/ml, the accepted cut-off point for active smoking.¹⁶

We classified parent figures described by their children as smoking "every day" or "sometimes" as smokers. We used the family affluence scale to measure socioeconomic status, and then split the sample into thirds corresponding to those living in low, medium, and high affluence families.¹⁷⁻¹⁹

Statistical analysis

We assigned cotinine values below the limit of detection (0.1 ng/ml) an imputed value randomly sampled from the left tail of a truncated log normal distribution. We report geometric mean cotinine concentrations. As individual children within a school class may be more similar with respect to secondhand smoke exposure than randomly selected children, standard methods of variance estimation may underestimate the true variance in the population. All analyses reported here take account of stratification and clustering within the survey design.

Changes in exposure to secondhand smoke in private and public locations were based on the number of pupils reporting someone smoking in a location versus all other responses. We used linear regression to assess the differences in mean cotinine concentrations between survey years, adjusting for age and family affluence. We did a separate linear regression analysis to assess the differences in mean cotinine

concentrations before and after legislation by number of parent figures who smoked.

RESULTS

Response rates

In total, 116 (68%) of 170 approached schools agreed to take part in the study before the legislation; 111 of the original 116 schools also participated at follow-up in 2007 (65% of originally approached schools). A total of 2559/2991 (86%) pupils completed the self report questionnaire in 2006, and 2424/2836 (85%) pupils completed the questionnaire in 2007. The final data sets contained 2532 pupil questionnaires and 2403 saliva samples in 2006 and 2389 pupil questionnaires and 2270 saliva samples in 2007. Schools that declined to participate did not have significantly different distributions from participating schools with respect to denomination, urban/rural classification, school size, and proportion of pupils receiving free school meals. Participating schools were representative of Scottish schools with respect to these indicators.

Sample characteristics

The mean age of pupils, proportion of boys and girls, and proportion of pupils living in each family structure (see bmj.com) and in each family affluence group were not significantly different before and after legislation. Most pupils in both survey years were classified as non-smokers on the basis of self report and cotinine concentrations below 15 ng/ml.

Population change in secondhand smoke exposure

Median cotinine concentration fell from 0.3 ng/ml to 0.2 ng/ml after legislation. The proportion of pupils with cotinine concentration below the limit of

Table 1 | Exposure to secondhand smoke in private and public locations before and after smoke-free legislation in Scotland. Values are numbers (percentages)

| Location | Yes, someone was smoking there | No-one was smoking there | I wasn't in this location yesterday | Don't know | Total |
|---|--------------------------------|--------------------------|-------------------------------------|------------|-------|
| Home (P=0.747*) | | | | | |
| 2006 | 668 (27.8) | 1550 (64.5) | 27 (1.1) | 159 (6.6) | 2404 |
| 2007 | 622 (27.4) | 1461 (64.3) | 19 (0.8) | 170 (7.5) | 2272 |
| Car (P=0.817*) | | | | | |
| 2006 | 155 (6.7) | 1448 (62.1) | 678 (29.1) | 49 (2.1) | 2330 |
| 2007 | 144 (6.5) | 1364 (61.3) | 669 (30.1) | 47 (2.1) | 2224 |
| Someone else's home (P=0.029*) | | | | | |
| 2006 | 266 (11.6) | 599 (26.1) | 1319 (57.5) | 111 (4.8) | 2295 |
| 2007 | 208 (9.5) | 632 (28.9) | 1236 (56.4) | 114 (5.2) | 2190 |
| Cafe or restaurant (P<0.001*) | | | | | |
| 2006 | 74 (3.2) | 96 (4.1) | 2125 (91.2) | 35 (1.5) | 2330 |
| 2007 | 21 (0.9) | 183 (8.2) | 1982 (89.3) | 33 (1.5) | 2219 |
| Bus or train (P=0.015*) | | | | | |
| 2006 | 36 (1.5) | 175 (7.4) | 2122 (89.7) | 33 (1.4) | 2366 |
| 2007 | 13 (0.6) | 211 (9.5) | 1972 (88.6) | 30 (1.3) | 2226 |
| Indoor leisure facility (P=0.102*) | | | | | |
| 2006 | 60 (2.6) | 445 (19.0) | 1709 (73.1) | 124 (5.3) | 2338 |
| 2007 | 41 (1.9) | 487 (22.1) | 1560 (70.8) | 115 (5.2) | 2203 |

*Tests for changes between survey years based on number of pupils reporting someone smoking in a location versus all other responses (including missing); significance levels for design adjusted χ^2 analyses shown.

detection increased from 20% to 34% after legislation. However, the proportion of pupils with higher cotinine concentrations did not change substantially. The adjusted mean cotinine concentration fell by 39% from 0.36 (95% confidence interval 0.32 to 0.40) ng/ml in 2006 to 0.22 (0.19 to 0.25) ng/ml in 2007.

Self reported exposure to secondhand smoke was higher in private locations than in public locations both before and after legislation (table 1). Exposure in pupils' own homes, the most reported location (27.8% in 2006 and 27.4% in 2007), or in a car (6.7% in 2006 and 6.5% in 2007) were similar before and after legislation. In contrast, reported exposure in someone else's home fell after legislation (11.6% in 2006 *v* 9.5% in 2007, $P=0.029$). Exposure to secondhand smoke in public places was reported by relatively few pupils before and after legislation, but a decline in exposure between survey years was reported in cafes or restaurants (3.2% in 2006 *v* 0.9% in 2007, $P<0.001$) and on buses or trains (1.5% in 2006 *v* 0.6% in 2007, $P=0.015$).

Displacement of parental smoking into the home

In each survey year more than 40% of pupils reported living with a parent figure who smoked (table 2). Geometric mean cotinine concentration decreased significantly between survey years, as when all pupils were included (adjusted geometric mean cotinine concentration 0.35 (0.32 to 0.38) ng/ml in 2006 and 0.21 (0.19 to 0.23) ng/ml in 2007, $P<0.001$), and increased significantly across groups ($P<0.001$) as the number of parent figures who smoked increased. The only interaction term that reached significance was that between survey year and parent figures in the home who smoked. Within each of the groups, a fall in geometric mean cotinine concentration occurred after legislation. However, this drop was statistically significant only among groups with lower levels of secondhand smoke exposure. Among pupils of non-smoking parent figures, geometric mean cotinine concentration fell 51% from 0.14 (0.13 to 0.16) ng/ml to 0.07 (0.06 to 0.08) ng/ml. Among pupils with only a father figure who smoked, mean cotinine concentration fell 44% from 0.57 (0.47 to 0.70) ng/ml to 0.32 (0.25 to 0.42) ng/ml. Among pupils living in households with only a mother who smoked or with both parents who smoked, geometric mean cotinine concentration fell 11%, but this was not statistically significant (table 2).

DISCUSSION

Main findings

Our study provides evidence of a population level change in exposure to secondhand smoke among children in primary school in Scotland after the introduction of smoke-free legislation. Secondhand smoke exposure fell by 39% between January 2006 and January 2007, as shown by a significant fall in geometric mean cotinine concentration. The greatest proportional reduction occurred among pupils living in households with lower levels of secondhand smoke exposure. Although a reduction occurred among pupils with higher levels of secondhand smoke exposure at home, this was relatively small and not statistically significant. For children with no parents who smoke, we conclude that this reduction must be largely due to lower secondhand smoke exposure in public places outside the home.

Using self report data, we found evidence of a reduction in secondhand smoke exposure in public places covered by the legislation. A fall in reported exposure to secondhand smoke when visiting other people's homes occurred after legislation. This finding suggests some modification of smoking behaviour in front of non-family members after the legislation.

We found little evidence of a change between survey years in reported exposure in pupils' own homes or in cars. As children were only asked to report on whether smoking took place in the home, rather than the extent of smoking, more subtle changes in smoking levels or practices would not be recorded.

This study provides no evidence that the smoke-free legislation has led to displacement of adult smoking from public places into the home.^{10,20} We found little difference in the reported proportion of parents who smoke or exposure in pupils' own homes and, regardless of parental smoking status, no evidence of an increase in secondhand smoke exposure as measured by cotinine concentration.

Information on secular changes in cotinine concentrations in this age group before legislation is limited. Findings are available for non-smoking 11-15 year olds in England.^{21,22} For this group overall, mean cotinine concentration fell by 52% over a 15 year period between 1988 and 2003. The change in levels in our study, a 39% fall in cotinine concentration in a single year, is an order of magnitude higher than the average

Table 2 | Geometric mean cotinine concentrations and 95% confidence intervals by number of parent figures who smoke, adjusted for age and family affluence, before and after smoke-free legislation in Scotland

| Parental smoking status | 2006 | | 2007 | | Ratio (95% CI) of mean cotinine concentration 2007:2006 | P value |
|------------------------------|--|-------------|--|-------------|---|---------|
| | Mean (95% CI) cotinine concentration (ng/ml) | No (%) | Mean (95% CI) cotinine concentration (ng/ml) | No (%) | | |
| Neither parent figure smokes | 0.14 (0.13 to 0.16) | 1240 (59.6) | 0.07 (0.06 to 0.08) | 1140 (58.3) | 0.49 (0.42 to 0.56) | <0.001 |
| Father figure only smokes | 0.57 (0.47 to 0.70) | 218 (10.5) | 0.32 (0.25 to 0.42) | 226 (11.6) | 0.56 (0.41 to 0.77) | <0.001 |
| Mother figure only smokes | 1.38 (1.18 to 1.62) | 309 (14.9) | 1.23 (1.03 to 1.48) | 301 (15.4) | 0.89 (0.71 to 1.13) | 0.314 |
| Two parent figures smoke | 1.94 (1.71 to 2.21) | 312 (15.0) | 1.74 (1.51 to 2.00) | 287 (14.7) | 0.89 (0.74 to 1.08) | 0.173 |
| Total | 0.35 (0.32 to 0.38) | 2079 | 0.21 (0.19 to 0.23) | 1954 | 0.60 (0.53 to 0.68) | <0.001 |

Cotinine confirmed non-smokers.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Passive smoking poses a significant health risk to adults and children
Smoke-free legislation has been shown to be effective in improving the health and wellbeing of adults

WHAT THIS STUDY ADDS

Exposure to secondhand smoke among children in their final year of primary school in Scotland fell after the introduction of smoke-free legislation
This reduction occurred particularly among groups with lower secondhand smoke exposure in the home
No evidence of increased secondhand smoke exposure in young people associated with displacement of parental smoking into the home was found

annual change seen in the English studies. This change in Scotland can arguably be attributed to the introduction of the Scottish smoke-free legislation.

Strengths of the study

This study evaluates national legislation and is based on a large nationally representative sample, which permits population level inference. We used an objective measure of exposure to secondhand smoke. Basing the survey in schools may have encouraged more honest reporting of parental smoking than if the survey had been done at home with parent figures present in the house.²³

Limitations of the study

A longitudinal study design with repeat measures is more robust, but we chose a repeat cross sectional design, as with a longitudinal design the effects of the smoke-free legislation could not have been disentangled from changes in the likelihood of secondhand smoke exposure associated with behavioural changes owing to pupils maturing. Use of the same schools before and after legislation minimised the variation between years in pupils' characteristics.

The school take-up at baseline was lower than expected given response rates in another national survey among this age group in Scotland.¹⁷ However, we detected no systematic bias in the final sample of schools arising from non-participation.

Children were asked only to report exposure to secondhand smoke on the day before the survey. Compared with our cotinine validated measures, which reflect secondhand smoke exposure in the previous three to five days, the self report data may underestimate secondhand smoke exposure.

Conclusions

The Scottish smoke-free legislation has made progress towards promoting health in children by reducing exposure to secondhand smoke. Nevertheless, little impact has been made on the higher levels of exposure in the home experienced by children whose mother figure or both parent figures smoke. Nineteen per cent of children in our sample were still exposed to secondhand smoke at a level (≥ 1.7 ng/ml) that has been shown to be harmful to arterial health.²⁴ Our

findings underline the importance of continuing to raise awareness of the health risks of passive smoking, supporting adults to implement smoke-free policies in their homes and cars, and promoting smoking cessation. Communication to adults that even low levels of secondhand smoke exposure can pose substantial health risk to children of all ages is particularly important.

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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

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.¹ A subsequent study of air quality in a random sample of 41 pubs in 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.² This is consistent with studies from other countries where similar legislation has been introduced.^{3,4}

Our study is part of a comprehensive evaluation of Scotland's smoke-free legislation.⁵ It aimed to determine if a measurable change occurred in exposure to secondhand smoke 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 has been conducted in most years since 1996 to monitor health related knowledge and behaviour.⁶ 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

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