Chapter 6
Reductions in exposure to secondhand smoke and effects on health due to restrictions on smoking

Introduction

Earlier chapters have reviewed the evidence that secondhand smoke (SHS) is harmful to health, and have described the range and extent of smoking restrictions that have been applied around the world. Chapter 6 attempts to answer these questions: do smoking restrictions reduce the exposure of nonsmokers to SHS, and if so by how much? And, do these reductions in exposure to SHS lead to evident improvements in health? We look first at smoking restrictions in the workplace, since this has been a major focus of tobacco control activities around the world in the last 20 years. Initially restrictions were voluntary and partial, covering some workplaces (such as white collar offices) more thoroughly than others, but in the last decade many countries have introduced legal restrictions on where smoking is permitted (as described in Chapter 3). This Chapter also includes an account of the much smaller body of scientific work conducted on smoking restrictions in cars and public settings other than workplaces.

Methods

A variety of searches were undertaken to identify studies reporting on the effects of smoking restrictions. The Web of Science was searched from 1990 to 2007 using the terms "Smoke Free" SAME ban*, "Smoke Free" SAME polic*, "Smoke Free" SAME law*, and "Smoke Free" SAME legislation. Other databases, including Google Scholar, PubMed, and the National Library of Medicine, were searched in a similar fashion using expressions such as "legislation" and "tobacco smoke pollution." Relevant material was also sought from the European Network for Smoking Prevention's GLOBALink.

Effects of restrictions on smoking in the workplace

The first comprehensive assesments of the damage caused to health by SHS appeared in the mid-1980s (National Research Council, 1986; U.S. Department of Health and Human Services, 1986; National Health and Medical Research Council, 1987). In many countries smoking was already restricted in buildings such as theatres and cinemas (due mostly to concerns about fire risks), and the Civil Aeronautics Board required nonsmoking sections on US commercial flights beginning in 1973. However, reports by authoritative agencies, such as the US Department of Health and Human Services, added considerable impetus to the spread of bans on smoking in public places and worksites (Rigotti, 1989; Fielding, 1991). These restrictions were, at first, adopted on an industry-by-industry basis (U.S. Department of Health and Human Services, 2006). For example, the Australian Federal Government banned smoking in all offices in 1986, several years ahead of the first smoke-free laws in that country. The New Zealand Smoke-free Environments Act of 1990 was one of the first pieces of national legislation that aimed to protect the health of nonsmoking employees by banning smoking in the workplace (although this particular law had many loop-holes) (Laugesen & Swinburn, 2000). Since that time, laws have been passed in many jurisdictions and the pace at which new restrictions are being introduced has increased recently (see Chapter 3 for a more detailed account of the history of smoking restrictions). In some jurisdictions, laws have been passed that prohibit smoking in almost all occupational settings. For example, in early 2004, Ireland was the first country to pass comprehensive smoke-free legislation, and many more jurisdictions have introduced partial bans.

Partial bans have contributed to a substantial reduction in population exposures to SHS in many countries. In California throughout the early 1990s, the spread of community level ordinances was associated with a diminishing proportion of the population exposed to cigarette smoke at work (e.g. 29% of nonsmokers were exposed in indoor workplaces in 1990, compared with 22.4% in 1993) (Pierce *et al.*, 1994). In New Zealand in 1991, 39% of indoor workers were exposed to SHS during tea and lunch breaks. Five years later that proportion fell to 24% as a result of the increasing number and extent of voluntary smoking restrictions in workplaces not covered by the Smoke-free Environments Act (Woodward & Laugesen, 2001). Since 1980, most of the reduction in population exposure to smoking at work in Australia has occurred prior to the introduction of legislation. Court cases and legal rulings on the issue of liability highlighted the risk of litigation for employers if they continued to permit smoking at work, and thus voluntary adoption of smoke-free policies was rapid in most workplaces, but with important exceptions. In many countries, it was the continuing high levels of exposure to SHS in blue collar workplaces, and in bars, restaurants, and gaming venues that led to pressure for comprehensive, statutory restrictions.

It is clear from Table 6.1 that countries now vary widely in the nature and extent of prohibitions on smoking. It is important to note that the so-called “total bans,” in countries like Ireland and New Zealand, in fact do not apply to absolutely all workplaces. In New Zealand, for example, prisons, hotel and motel rooms, and long-term nursing establishments have partial exemption. Smoking is still permitted in outdoor dining and drinking areas, which means employees remain at risk of exposure to SHS (albeit much less than indoors). In some countries there are nationwide restrictions; elsewhere the responsibility for smoke-free legislation rests at the level of provincial or city authorities. There may be considerable variation in tobacco policies within countries (e.g. in Canada, such laws are the business of provincial governments and there is not a common view between the provinces on smoking bans). In some countries, like the USA, laws and regulations have been passed by multiple levels of government.

Studies also vary considerably in design and the methods used to measure exposure to SHS. These include direct observation of smoking and the smokiness of venues, questionnaires eliciting perceptions of exposure to SHS, air sampling, and biomarkers (mostly cotinine in saliva and urine, and nicotine in hair). The most common study type has been the cross-sectional survey with population samples drawn before and after the implementation of legislation. There have also been panel studies, in which the same participants are questioned at numerous points in time, and multiple cross-sectional representative samples of the population (e.g. the California Tobacco Surveys). A minority of studies have included geographic controls - study populations drawn from jurisdictions not affected by legislation and followed over the same period of time (Fong *et al.*, 2006; IARC, 2008).

Despite the heterogeneity of smoking restrictions and study designs, the results listed in Table 6.1 show some common patterns. In every country included in the table, the introduction of comprehensive legislation banning smoking in workplaces has been associated with a substantial reduction in exposure to SHS. Similar results have been obtained in studies of comprehensive smoking restrictions applied at levels of states and municipalities. For instance, an 80-90% reduction in polycyclic aromatic hydrocarbons (PAHs) in six Boston bars following implementation of smoke-free ordinances was observed (Repace *et al.*, 2006b). A study of 14 bars and restaurants from western New York State found a 90% reduction in $PM_{2.5}$ levels from a mean of 412 μg/m^3 to 27 μg/m^3 post-legislation (Travers *et al.*, 2004).

Table 6.1 Studies that report the effect of legislation restricting smoking in the workplace on exposure to SHS

Reference/location	Study participants	Study design	Restriction on smoking	Measure of exposure to SHS	Levels of exposure reported	Comments
Evidence from Europe						
Heloma *et al.*, 2001 Finland	Pre-Act: 967 employees Winter 1994-1995 Post-Act: 1035 employees Winter 1995-1996	Repeated cross-sectional studies	March 1995- Reformed Tobacco Control Act: Smoking prohibited on all public premises of workplaces	Vapour-phase nicotine	1994-1995: $PM_{2.5}$ in Industrial places 1.2 $\mu g/m^3$ Service sector 1.5 $\mu g/m^3$ Offices 0.4 $\mu g/m^3$ 1995-1996: $PM_{2.5}$ in Industrial places 0.05 $\mu g/m^3$ Service sector 0.2 $\mu g/m^3$ Offices 0.1 $\mu g/m^3$	
				Self-reported SHS exposure	1994-1995: SHS 18.6% 1995-1996: SHS 9.1 ($p<0.001$)	Proportion of employees reporting daily exposure to SHS for 1-4 hours
				Self-reported daily smoking prevalence	1994-1995: prevalence 30% 1995-1996: prevalence 25% ($p=0.021$)	Prevalence of daily smoking among employees
Heloma & Jaakkola, 2003 Finland	1994-95: 880 1995-96: 940 1998: 659 (post-law) Studied in eight workplaces in the Helsinki metropolitan area	Repeated cross-sectional studies	March 1995- Reformed Tobacco Control Act: Smoking prohibited on all public premises of workplaces	Indoor air nicotine concentrations Self-reported exposure to SHS Self-reported smoking behaviour	Median indoor airborne nicotine concentrations: 1994-95: 0.9 $\mu g/m^3$ 1995-96 and 1998: 0.1 $\mu g/m^3$ 1994: 51% 1995: 17% 1998: 12% From 30% to 25%; remained at 25% in the last survey three years later (1998)	Indoor air nicotine: 41 sites in 1994-95, 40 sites in 1995-96, 18 sites in 1998 Employees exposure to SHS for at least one hour daily. Respondents' daily smoking prevalence
Johnsson *et al.*, 2006 Finland	20 restaurants and bars with a serving area larger than 100 m² from three Finnish cities	1999 - Indoor air quality assessed (six months Pre-act) 2000 - six months Post-act 2002 - when 50% of clientele area should be smoke-free	1 March 2000 - Finnish Tobacco Act amended to include restrictions on smoking in all Finnish restaurants and bars with certain exceptions	Indoor air nicotine concentration, 3-EP, and TVOC by thermo-desorption-gas chro-matography-mass spectrometry	Geometric mean (GM) nicotine concentration All Pre-ban: 7.1 $\mu g/m^3$ Post-ban: 7.3 $\mu g/m^3$ Dinning Pre-ban: 0.7 $\mu g/m^3$ Post-ban: 0.6 $\mu g/m^3$ Bars/Taverns Pre-ban: 10.6 $\mu g/m^3$ Post-ban: 12 .7 $\mu g/m^3$ Disco Pre-ban: 15.2 $\mu g/m^3$ Post-ban: 8 .1 $\mu g/m^3$	In this study, partial smoking restrictions did not reduce SHS concentrations in workplaces

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Johnsson *et al.*, 2006 Finland		2004 - when entire Act was in force			3-ethenylpyridine (3-EP) concentration Pre-ban: 1.2 μg/m³ Post-ban: 1.7 μg/m³ Total Volatile Organic Compounds (TVOC) Pre-ban: 250 μg/m³ Post-ban: 210 μg/m³	
			Ventilation rate		All establishments in the survey had mixed ventilation (i.e. dilution ventilation and none had displacement ventilation)	
Allwright *et al.*, 2005 Ireland	329 bar staff from three areas of the Republic and one area in Northern Ireland (UK) Pre-ban: Sep 2003-March 2004 Post-ban: Sep 2004-March 2005	Comparisons	2002 Public Health (Tobacco) Act (Commencement) Order 2004: Smoking is forbidden in enclosed places of work in Ireland, including office blocks, various buildings, public houses/bars, restaurants, and company vehicles (cars and vans)	Salivary cotinine concentration	*In the Republic:* 80% reduction Pre-ban: 29 nmol/l (95% CI=18.2-43.2 nmol/l) Post-ban: 5.1 nmol/l l (95% CI=2.8-13.1 nmol/l) *In Northern Ireland:* 20% reduction Pre-ban: 25.3 nmol/l (95% CI=10.4-59.2 nmol/l) Post-ban: 20.4nmol/l l (95% CI=13.2-33.8 nmol/l)	
				Respiratory and sensory irritation symptoms	*In the Republic* - *Respiratory symptoms* Pre-ban (baseline): 65% (one or more respiratory symptoms) Post-ban: 25%-49% (p=0.001) - *Sensory symptoms* Pre-ban: 67% Post-ban: 45% (p<0.001) *In Northern Ireland* - *Respiratory symptoms* Pre-ban (baseline): 45% (one or more respiratory symptoms) Post-ban: 45% - *Sensory symptoms* Pre-ban: 75% Post-ban: 55% (p=0.13)	

Reference/location	Study participants	Study design	Restriction on smoking	Measure of exposure to SHS	Levels of exposure reported	Comments
Evidence from Europe						
Allwright *et al.*, 2005 Ireland				Self-reported exposure to SHS	*Work-related exposure* *In the Republic* Pre-ban: 40 hours Post-ban: 0 hours (p<0.001) *In Northern Ireland* Pre-ban: 42 hours Post-ban: 40 hour (p=0.02) *Outside work* *In the Republic* Pre-ban: 4 hours Post-ban: 0 hours (p<0.001) *In Northern Ireland* Pre-ban: 0 hours Post-ban: 2.5 hour (p=0.41)	
Mulcahy *et al.*, 2005 Ireland	Cohort study, 35 workers in 15 city hotels, a random sample from 20 city centre bars (range 400-5000 square feet)	Repeated measures of exposures before and after legislation. Saliva samples obtained 2-3 weeks before and 4-6 weeks after smoking ban. Airborne nicotine was measured for 7-10 hours on the Friday preceding the ban and six weeks later	29 March 2004 - Act effective: Smoking banned in all bars, restaurants, cafes, and hotels (excluding bedrooms, outdoor areas, and properly designed smoking shelters)	Salivary cotinine concentration Air nicotine concentration Duration of self-reported exposures to SHS	69% reduction Pre-ban: 1.6 ng/ml Post-ban: 0.5 ng/ml (SD: 1.29; p < 0.005) Overall: 74% reduction (range 16-99%) 83% reduction Pre-ban: 35.5 mg/m^3 Post-ban: 5.95 mg/m^3 (p < 0.001) Pre-ban: 30 hours Post-ban: 0 hours (p < 0.001)	
Fong *et al.*, 2006 Ireland and UK	1679 adult smokers aged >18 years from Ireland (n=1071) and UK (n=608); 1185 completed the survey Pre-ban: Dec 2003-Jan 2004 Post-ban: Dec 2004-Jan 2005	Prospective cohort study	29 March 2004 - Republic of Ireland implemented comprehensive smoke-free legislation in all workplaces, including restaurants and pubs, with no allowance for designated smoking rooms and few exemptions	Respondents' reports of smoking in key public venues	Bars/pubs, *Ireland* Pre-ban: 98%; Post-ban: 5% (p < 0.0001) Bars/pubs, *UK* Pre-ban: 98%; Post-ban: 97% (p=0.462) Restaurants, *Ireland* Pre-ban: 85%; Post-ban: 3% (p < 0.0001)	

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Evidence from Europe						
Fong *et al.*, 2006 Ireland and UK					Bars/pubs, *UK* Pre-ban: 78%; Post-ban: 62% ($p<0.001$) Shopping malls, *Ireland* Pre-ban: 40%; Post-ban: 3% ($p < 0.0001$) Bars/pubs, *UK* Pre-ban: 29%; Post-ban: 22% ($p=0.012$) Workplaces, *Ireland* Pre-ban: 62%; Post-ban: 14% ($p < 0.0001$) Bars/pubs, *UK* Pre-ban: 37%; Post-ban: 34% ($p=0.462$) (adjusted OR=8.89; 95% CI=8.14-9.33, $p < 0.0001$)	
Valente *et al.*, 2007 Italy	40 establishments in the city of Rome (14 bars, six fast food restaurants, eight restaurants, six video game parlours, six pubs)	Repeated measures of indoor air quality were taken in Nov/Dec (before the law was in effect), and again in March/April 2005 and Nov/Dec 2005 (after the law was in effect)	10 January 2005 - A smoking ban in all indoor public places was enforced in Italy	Exposure to environmental tobacco smoke was measured by determining $PM_{2.5}$ and the number of ultrafine particles (UFP) Urinary cotinine concentration	$PM_{2.5}$ Pre-ban (Jan 2005): 119.3 mg/m^3 (95% CI=75.7-162.8) Post-ban (Mar/Apr 2005): 38.2 mg/m^3 (95% CI=27.5-48.8) (Nov/Dec 2005): 43.3 mg/m^3 (95% CI=33.2-53.3) UFP Pre-ban (Jan 2005): 76 956 pt/cm^3 (95% CI=59 723-65 354) Post-ban (Mar/Apr 2005): 38 079 pt/cm^3 (95% CI=25 499-50 658) (Nov/Dec 2005): 51 692 pt/cm^3 (95% CI= 38 030-65 354) Urinary cotinine Pre-ban (Jan 2005): 17.8 ng/ml (95% CI=14-21.6)	

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Evidence from Europe						
Valente *et al.*, 2007 Italy				Subjective exposure to passive smoke in the workplace and at home	Post-ban (Mar/Apr 2005): 5.5 ng/ml (95% CI=3.8-7.26) (Nov/Dec 2005): 3.7 ng/ml (95% CI=1.8-5.6) There was a reduction in subjective exposure to SHS at the workplace in the post-law periods (p<0.0005) (data not shown)	
Ellingsen *et al.*, 2006 Norway	93 employees from 13 bars and restaurants in Oslo during the last month before the smoking ban (1 June 2004), and three months after implementation (Sep 2004-Feb 2005)	Prospective study with exposure measures one month before and three months after legislation	1988 - Norway enacted comprehensive legislation on smoking in public places; restaurants and bars exempt Revision of Environmental Tobacco Smoke Act was proposed. Total smoking ban in bars, nightclubs, and restaurants enacted 1 June 2004	Level of airborne contaminants (airborne nicotine, airborne dust) Urinary cotinine concentration	Total dust Pre-ban: 262 μg/m^3 (range 52-662) Post-ban: 77 μg/m^3 (range Nd-261) (p<0.001) Nicotine Pre-ban: 28.3 μg/m^3 (range 0.4-88.0) Post-ban: 0.6 μg/m^3 (range Nd-3.7) (p<0.001) Non-snuffing nonsmokers Pre-ban: 9.5 μg/mg creatinine (95% CI=6.5-13.7) Post-ban: 1.4 μg/mg (95% CI=0.8-2.5) (p < 0.001) Non-snuffing smokers Pre-ban: 1444 μg/mg (95% CI=957-2180) Post-ban: 688 μg/mg (95% CI=324-1458) (p < 0.05)	Nd: not detected
Akhtar *et al.*, 2007 Scotland	2559 primary school children surveyed before the smoke-free legislation (January 2006) 2424 surveyed after implementation (January 2007)	Repeated cross-sectional survey	2005 - Smoking, Health and Social Care (Scotland) Act: Smoking is not permitted in most fully and substantially enclosed public places in Scotland (implemented 26 March 2006)	Salivary cotinine concentrations Reports of parental smoking Self-reported exposure to tobacco smoke in public and private places before and after legislation	39% reduction 2006: 0.36 ng/ml (95% CI=0.32-0.40) 2007: 0.22 ng/ml (95% CI=0.19-0.25) 51% reduction in households with no parental smoking 2006: 0.14 ng/ml (95% CI=0.13-0.16) 2007: 0.07 ng/ml (95% CI=0.06-0.08) Cafes/restaurants 2006: 3.2%; 2007: 0.9%; p<0.001 Buses and trains 2006: 1.5%; 2007: 0.6%; p=0.015	Adjusted for age and family affluence Lack of a comparison group to control for secular changes in exposure to SHS No evidence of displacement of adult smoking from public places into home

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Reference/location	Study participants	Study design	Restriction on smoking	Measure of exposure to SHS	Levels of exposure reported	Comments
Evidence from Europe						
Haw & Gruer, 2007 Scotland	Adults 18-74 years contacted at home Pre-ban: n=1815 1 Sept - 20 Nov 2005 9 Jan - 25 March 2006 Post-ban: n=1834 1 Sept - 10 Dec 2006 8 Jan - 2 Apr 2007	Repeated cross-sectional survey	2005 - Smoking, Health and Social Care (Scotland) Act: Smoking is not permitted in most fully and substantially enclosed public places in Scotland (implemented 26 March 2006)	Salivary cotinine concentration Self-reported exposure to SHS in public and private places Self-reported smoking restriction in homes and in cars	39% reduction (95% CI= 29%-47%) 2005-2006: 0.43 ng/ml (95% CI=0.39-0.47) 2006-2007: 0.26 ng/ml (95% CI=0.23-0.29) Pub: OR=0.03; 95% CI=0.02-0.05 Work: OR=0.32; 95% CI=0.23-0.45 Public Transport: OR=0.29; 95% CI=0.15-0.57 Other enclosed public place: OR=0.25; 95% CI=0.17-0.38 (not in homes or in cars) Reference: Self-reported exposure to SHS before legislation Complete/partial ban in homes: OR=1.49; 95% CI=1.26-1.76	Lack of a comparison group to identify secular trends unrelated to legislation No evidence of displacement of adult smoking from public places into home ORs adjusted for sex, education, and deprivation category Exposure to SHS significantly reduced only in enclosed public places (not private) covered by the law
Semple *et al.*, 2007a,b Scotland	41 randomly selected pubs in two cities Pre-ban : 26 March 2006 Post-ban: eight weeks later	Repeated measures of indoor air quality before and after legislation	2005 - Smoking, Health and Social Care (Scotland) Act: Smoking is not permitted in most fully and substantially enclosed public places in Scotland (implemented 26 March 2006)	$PM_{2.5}$ was measured for 30 minutes in each bar in 1 or 2 visits in eight weeks prior to and 8 weeks after legislation	Pre-ban: $PM_{2.5}$ 246 $\mu g/m^3$ (range 8-902 $\mu g/m^3$) Post-ban: $PM_{2.5}$ 20 $\mu g/m^3$ (range 6-104 $\mu g/m^3$)	
Galan *et al.*, 2007 Spain	1750 participants from the non-institutionalised population aged 18-64 years prior to the law (Oct-Nov 2005), and 1252 participants immediately after the law was enacted (Jan-July 2006)	Cross-sectional population-based study	January 2006 - A national tobacco control law introduced in Spain. Includes a total ban of smoking in workplaces and a partial limitation of smoking in bars and restaurants	Self-reported questionnaire to gather levels of passive exposure to SHS at home, work, in bars, and restaurants	At home: OR=0.84 (95% CI=0.11-0.19) ($p < 0.001$) 2005 Pre-ban: 34.3% (95% CI=32.1-36.6) 2006 Post-ban: 30.5% (95% CI=27.9-33.2)	

Reference/location	Study participants	Study design	Restriction on smoking	Measure of exposure to SHS	Levels of exposure reported	Comments
Evidence from Europe						
Galan *et al*., 2007 Spain					At work: OR=0.14 (95% CI=0.71-1.00)(p=0.044) 2005 Pre-ban: 40.5% (95% CI=37.5-43.6) 2006 Post-ban: 9.0% (95% CI=7.0-11.3) Bars and restaurants: OR=0.54 (95% CI=0.37-0.80) (p<0.001) 2005 Pre-ban: 0.30% (95% CI=0.20-0.44) 2006 Post-ban: 0.16% (95% CI=0.10-0.24) Results were similar for smoking and nonsmoking populations	
Fernandez *et al*., 2008 Spain	Air quality measured in 44 hospitals before and after a national ban on smoking in the workplace	Before and after environmental measures	January 2006 - Spanish Smoking Control Law. Exemptions apply for some hospitality venues	Vapour phase nicotine in multiple locations Sep-Dec 2005 and Sep-Dec 2006	56.5% reduction 2005: 0.23 $\mu g/m^3$ (IQR 0.13-0.63) 2006: 0.10 $\mu g/m^3$ (IQR 0.02-0.19)	IQR: Inter-quartile range
Evidence from Australia and New Zealand						
Cameron *et al*., 2003 Australia	A stratified random sample of 1078 members of the Victorian Branch of the Australian Liquor, Hospitality, and Miscellaneous Workers Union interviewed by telephone in September 2001	Cross-sectional survey	Four main categories of smoking restrictions were constructed based on the participants' responses: total ban, ban at usual work station, no ban at usual workstation, and no restrictions	Self-reported exposure to SHS (hours per day)	Total bans: No exposure: 100% > 0-≤7.5 hours of exposure: 0% > 7.5 hours of exposure: 0% Banned at workstation: No exposure: 76% > 0-≤7.5 hours of exposure: 20% > 7.5 hours of exposure: 4% No ban at workstation: No exposure: 4% > 0-≤7.5 hours of exposure: 51% > 7.5 hours of exposure: 45% No restriction: No exposure: 4% > 0-≤7.5 hours of exposure: 49% > 7.5 hours of exposure: 47%	

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Reference/location	Study participants	Study design	Restriction on smoking	Measure of exposure to SHS	Levels of exposure reported	Comments
Evidence from Australia and New Zealand						
Al-Delaimy *et al.*, 2001a New Zealand	117 workers from 62 workplaces (restaurants or bars) from two cities (Wellington and Auckland) were surveyed from Dec-March 1997/98 and 1998/99, respectively	Cross-sectional survey	1990 - New Zealand introduced smoke-free environment legislation which prohibited smoking in most workplaces. Restaurants could elect to prohibit smoking, but were required to designate only 50% of seating as smoke-free; bars were exempt	Geometric means of hair nicotine level in nonsmoking workers (tested by high performance liquid chromatography)	Smoke-free policy (nonsmoking workers) 100% smoke-free restaurants: 0.62 ng/mg (95% CI=0.5-0.7) In bars with no restriction: 6.69 ng/mg (95% CI=4.1-10.5) In places with partial restriction: 2.72 ng/mg (95% CI=1.9-4) In places with no restriction: 6.69 ng/mg (95% CI=4.1-10.5) Smoke-free policy (smoking workers): 7.92 ng/mg (95% CI=5-12)	
Bates *et al.*, 2002 New Zealand	Three categories of non-smoking subjects (n=92): 1) employees in bars and restaurants that permitted smoking by customers; 2) employees in hospitality premises that did not permit customers to smoke; 3) employees in smoke-free government ministries and departments	Repeated cross-sectional survey. All interviews took place between June-Oct 2000	1990 - New Zealand introduced smoke-free environment legislation which prohibited smoking in most workplaces. Restaurants could elect to prohibit smoking, but were required to designate only 50% of seating as smoke-free; bars were exempt	Salivary cotinine concentration was measured pre- and post-shift or work day	Government employees: Pre-shift: 0.12 ng/g; Post-shift: 0.08 ng/g Hospitality workers (smoke-free workplaces) Pre-shift: 0.37 ng/g; Post-shift: 0.28 ng/g Hospitality workers (smoking only in designated area) Pre-shift: 1.12 ng/g; Post-shift: 1.68 ng/g Hospitality workers (no smoking restrictions) Pre-shift: 1.60 ng/g; Post-shift: 3.38 ng/g The permissiveness of the smoking policy of a workplace was directly associated with the likelihood of an increase in salivary cotinine concentration at work.	

Reference/location	Study participants	Study design	Restriction on smoking	Measure of exposure to SHS	Levels of exposure reported	Comments
Evidence from Australia and New Zealand						
Fernando *et al.*, 2007 New Zealand	Nonsmokers living or working in a nonsmoking environment aged 24-45 years, randomly selected bars in three cities. Pre-ban: July-Sept 2004-Winter and again in Oct/Nov-Spring Post-ban: Same times in 2005	Panel study with exposure measures before and after legislation	10 Dec 2004 - Smoking not permitted in any indoor place of work including bars, restaurants, and hotels	Count of the number of cigarettes lit in three 10 min intervals	Pre-ban 2004 (Winter): 889 (Spring): 928 Post-ban 2005 (Winter): 0 (Spring): 1	Study controlled for secular trends in exposure to SHS at home and in outdoor public places
				Salivary cotinine levels were measured before and after a three hour visit	Pre-ban 2004 (Winter): 0.76 ng/ml (SE 0.05 ng/ml) (Spring): 0.54 ng/ml (SE 0.41 ng/ml) Post-ban 2005 (Winter): 0.10 ng/ml (SE 0.01 ng/ml) (Spring): 0.07 ng/ml (SE 0.01 ng/ml)	SE: standard error of mean
				Subjective assessment of ventilation was measured by a questionnaire	Increases in cotinine strongly correlated with the volunteers' subjective observation of ventilation, air quality, and counts of lit cigarettes.	
Evidence from USA						
Eisner *et al.*, 1998 California, USA	53 daytime bartenders from 25 bars and taverns in San Francisco Baseline: 1 Dec - 31 Dec 1997 Follow-up: 1 Feb - 28 Feb 1998	Panel study with exposure measures before and after legislation	1 Jan 1998 - California State Assembly Bill 13 amended the California Labour Code to prohibit smoking in bars and taverns	Respiratory and sensory irritation symptoms	1997 Pre-ban: 39 bartenders (74%) with respiratory symptoms, 77 % with at least one sensory irritation 1998 Follow-up: 17 bartenders (32%) still symptomatic, 19% with sensory irritation	
				Self-reported SHS exposure	1997 Pre-ban: All 53 bartenders reported SHS exposure (A median exposure of 28 hours per week) 1998 Follow-up: Median SHS exposure per week: 2 hours ($P<0.001$) Despite the prohibition of smoking, 29 subjects (55%) continued to report some SHS exposure (≥1 hour/wk) while working as bartenders.	

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Evidence from USA						
Pion & Givel, 2004 Missouri, USA	Airports: Lambert, St Louis and Seattle-Tacoma (Sea-Tac) International	Measures of indoor SHS with varying levels of restrictions on smoking. Testing in nonsmoking areas adjacent to a designated smoking room conducted at Lambert Airport in 1997-98 and again in 2002. Tests also performed in 1998 inside nominally smoke-free Sea-Tac.	Lambert Airport: smoking is allowed in shops, restaurants, cocktail lounges, gate areas, and airline clubs; restricted smoking in the terminal and concourses	Ambient nicotine vapour level	Lambert Airport 1997-1998: 0.46 $\mu g/m^3$ 2002: 0.72 $\mu g/m^3$ Inside nonsmoking Sea-Tac Airport 1998: 0.15 $\mu g/m^3$	Smoking rooms in airport are a source of SHS exposure for nonsmokers in adjacent nonsmoking areas
Repace, 2004 Delaware, USA	A casino, six bars, and a pool hall in Wilmington metropolitan area Pre-ban: 15 Nov 2002 Post-ban: 24 Jan 2003	Cross-sectional air quality survey before/ after enactment of statewide Clean Indoor Air law	27 Nov 2002 - Delaware Clean Indoor Air Act was amended to ban smoking in restaurants, bars, and casinos (hospitality venues that were excluded in the original Act)	Real-time measurements were made of RSP-$PM_{2.5}$ and PPAH	2002 Pre-ban: Outdoor of hotel room, RSP=9.5 $\mu g/m^3$ Indoor of hospitality, RSP=231 $\mu g/m^3$ (SD: 208 $\mu g/m^3$) 2003 Post-ban: RSP (range = 2.5%-25%, mean 9.4%) 2002 Pre-ban: PPAH= 134 ng/m^3 2003 Post-ban: (range = 0.5%-11%, mean 4.7%)	RSP: respirable size particles PPAH: particulate polycyclic hydrocarbons
Farrelly *et al.*, 2005 New York, USA	104 nonsmoking workers aged ≥18 years, recruited from restaurants, bars, and bowling facilities.	Panel study	26 March 2003 - New York State legislature passed the statewide Clean Air Act prohibiting smoking in	Saliva cotinine concentration	2003 Pre-ban: 3.6 ng/ml (95% CI=2.6=4.7 ng/ml) 2004 Post-ban: 0.8 ng/ml (95% CI=0.4-1.2 ng/ml)	Half of baseline sample lost to follow-up, due to changes in employment and moving out of state.

Reference/location	Study participants	Study design	Restriction on smoking	Measure of exposure to SHS	Levels of exposure reported	Comments
Evidence from USA						
Farrelly *et al.*, 2005 New York, USA	Pre-ban: In the period of recruitment (before legislation) Post-ban: 12 months later		all places of employment, including restaurants, bars, and bingo and bowling facilities. 24 July 2003 - law went into effect	Self-reported exposure to SHS in the workplace and other settings in the previous four days	2003 Pre-ban: Mean hours of exposure to SHS in hospitality jobs: 12.1 hours (95% CI=8-16.3 hours) 2004 Post-ban: Mean hours of exposure to SHS in hospitality jobs: 0.2 hours (95% CI=0.1-0.5 hours)	However, comparing baseline statistics for those who participated across all waves to those who dropped out of the study shows no substantial difference, suggesting no bias was introduced due to attrition
Hahn *et al.*, 2006 Kentucky, USA	105 bar and restaurant workers aged ≥18 years from 44 restaurants, and six bars in Lexington Pre-ban: 27 April 2004 Post-ban: three and six months later	Panel study	July 2003 - Lexington-Fayette Urban County Council passed Kentucky's first smoke-free law. It prohibited smoking in most public places, including, but not limited to, restaurants, bars, bowling alleys, bingo halls, convenience stores, Laundromats, and other businesses open to the public. 27 April 2004 - law went into effect	Hair nicotine samples were obtained from subjects as an objective measure of SHS exposure Self-reported exposure to SHS	2004 Pre-ban: 1.79 ng/mg (SD: 2.62) 2004 Post-ban: 1.30 ng/mg (SD: 2.42) Comparing nonsmokers and smokers on change in hair nicotine, the average decline was significant among nonsmokers (t=2.3, p=0.03), but smokers did not exhibit a significant change over time (t=0.3, p=0.8) 2004 Pre-ban: (in past 7 days): 31 hours/wk 2004 Post-ban: (in past 7 days): 1-2 hours/wk	High attrition rate (43% at six months follow-up) Intention to treat analysis was used to account for the potential effects of attrition
Pickett *et al.*, 2006 USA	5866 nonsmoking adults (≥ 20 years) sampled from the National Health and Nutrition Examination Survey (NHANES)	Repeated cross-sectional studies	Survey locations were categorised into: Extensive coverage if at least one smoke-free law (work, restaurant, bar) existed at the county or state level and covered the entire county; limited coverage if there was not	Serum cotinine level	The median cotinine level was below the limit of detection (<0.05 ng/ml) for all three groups Adults at locations with extensive coverage of smoking restrictions showed no detection of cotinine up through the 75th centile. The 90th [0.07 ng/ ml (95% CI=0.03-0.12)] and 95th centile [0.16 ng/ ml (95% CI=0.11-1.49)] values in the extensive coverage group were 80% lower than for the no coverage group	Smoke-free law classification scheme is not part of the sample design of NHANES, which limits the generalisability of the study findings

Table 6.1 Studies that report the effect of legislation restricting smoking in the workplace on exposure to SHS

Reference/location	Study participants	Study design	Restriction on smoking	Measure of exposure to SHS	Levels of exposure reported	Comments
Evidence from USA						
Pickett *et al.*, 2006 USA			a state or county smoke-free law, but there was at least one municipality within the county with a smoke-free law (work, restaurant, bar); no smoke-free law coverage at the state, county, or city level		After adjusting for confounders (race, age, education, restaurant visit), men and women residing in counties with extensive coverage had 0.10 (95% CI=0.06-0.16) and 0.19 (95% CI=0.1-0.34) times the odds of SHS exposure compared to those residing in counties without a smoke-free law	
Alpert *et al.*, 2007 Massachusetts, USA	27 hospitality venues were selected from five Massachusetts towns that either did not have a smoking policy or had a very weak one Pre-ban: 23-29 June 2004 Post-ban: 27 Oct-1 Dec 2004	Repeated cross-sectional survey	5 July 2004 - Massachusetts Smoke-free Law went into effects smoking completely banned in all workplaces, including restaurants and bars	To assess indoor air quality: Change in RSP less than 2.5 microns in diameter ($PM_{2.5}$) from pre-law to post-law Observations were made to determine the number of people present and the number of burning cigarettes	93% reduction 2004 Pre-ban (Jun): $PM_{2.5}$ 206 $\mu g/m^3$ Post-ban (Oct-Dec): $PM_{2.5}$ 14 $\mu g/m^3$ 2004 Pre-ban (Jun): smoking density: 0.89 burning cigarettes per 100 m^3 Post-ban (Oct-Dec): smoking density: 0.00 burning cigarettes per 100 m^3	Small sample - less likely to be representative
Biener *et al.*, 2007 Massachusetts (MA), USA	Smokers and recent quitters (aged 18-30 years) from Boston (n=83), and another 203 Massachusetts cities and towns (n=903) that did not adopt smoking bans prior to July 2004 Pre-ban: Jan 2001 and June 2002 Post-ban: 5 May 2003 and before 5 July 2004	Panel study with measure of exposure	May 2003 - City of Boston implemented a smoke-free workplace ordinance that extended the existing ban on smoking in restaurants to all workplaces in the city, including bars	Self-reported exposure to SHS measured by proportion of respondents who reported seeing smoking by other people when they went out to a bar or a nightclub Self-reported exposure to SHS at home	In Boston: 69.2% (95% CI=51.0-82.9) In other MA town: 25.1% (95% CI=18.9-32.6) (p=0.000) In Boston: 66.9% (95% CI=57.1-79.7) In other MA town: 62.5% (95% CI=58.5-66.4) There was no significant difference in exposure to SHS at home.	Small sample - less likely to be representative Older nonsmokers were not included in the research design

Reference/location	Study participants	Study design	Restriction on smoking	Measure of exposure to SHS	Levels of exposure reported	Comments
Evidence from USA						
Centers for Disease Control and Prevention, 2007b New York, USA	2008 nonsmokers age ≥18 years who participated in New York Adult Tobacco Survey (NYATS). Pre-ban: 26 June 2003 (<1 month before implementation of the statewide law) Post-ban: 30 June 2004 (1 week after implementation)	Repeated cross-sectional survey with measures of exposure before and after implementation of the 2003 New York state ban on smoking	24 July 2003 - New York City amended its anti-smoking law to include all restaurants, bars, and private clubs	Salivary cotinine concentration Self-reported exposure to SHS	47.4% reduction 2003: 0.078 ng/ml (95% CI=0.054-0.111) 2004: 0.041ng/ml (95% CI=0.036-0.047) Restaurant/bar respondents 2003: 19.8% (95% CI=15.6-24.1) 2004: 3.1% (95% CI= 2.0-4.2) Restaurant patrons 2003: 52.4% (95% CI=41.5-63.4) 2004: 13.4% (95% CI= 9.5-17.3)	Relatively low exposures to SHS in workplaces likely attributed to local smoke-free laws and voluntary workplace smoking restrictions in place before implementation of the state law
Lee *et al.*, 2007 Kentucky, USA	Nine hospitality venues and one bingo hall in Georgetown that allowed smoking before the enforcement of the law. Pre-ban: 10 July 2005 Post-ban: 1-week, 2-weeks, and 3-months after the legislation	Measures of indoor air quality	July 2005 - Georgetown, Kentucky City Council passed a 100% smoke-free public and workplace law. It was implemented 1 October 2005	Average indoor $PM_{2.5}$ concentration was measured using a Sidepak monitor	*In hospitals* Pre-ban: 84 $\mu g/m^3$ Post-ban (1 week later): 18 $\mu g/m^3$ (21% of the mean) *In bingo mall* Pre-ban: 226 $\mu g/m^3$ Post-ban (2 weeks later): 748 $\mu g/m^3$ (3 months later): 43 $\mu g/m^3$	

Partial restrictions have been less effective than wide-reaching statutes. By way of illustration: in Spain, reductions in airborne nicotine were observed in hospitality venues that applied smoking bans, but not in venues that allowed smoking to continue (as permitted by the legislation implemented in 2006 (Luschenkova *et al.*, 2008). Amongst Spanish hospitality workers, salivary cotinine levels fell overall, but the drop was more marked among workers in venues where smoking was totally prohibited (55.6% fall compared with 10.6% where smoking continued) (Fernandez *et al.*, 2009). Comparable studies from countries with comprehensive bans report much larger reductions in salivary cotinine levels among hospitality workers (Allwright *et al.*, 2005; Semple *et al.*, 2007a).

Another example of partial bans is Georgia: in 2003 the country restricted smoking in health care facilities to designated smoking areas. In 2007, a study of airborne nicotine and $PM_{2.5}$ levels found evidence of smoking in many areas that were theoretically smoke-free; the highest levels of nicotine were observed in medical staff offices (Schick *et al.*, 2008). In Finland, no improvement in air quality was found after legislation in March 2000 that introduced nonsmoking areas in some bars and restaurants (Johnsson *et al.*, 2006).

What might explain the reduction in exposures to SHS following the implementation of comprehensive smoke-free legislation? This reduction is typically an 80-90% decrease from levels observed pre-legislation. The size of the changes and the consistency with which this result is reported effectively rules out chance. Biases in reporting and publishing may favour the dissemination of positive studies over those with equivocal or negative results, but it is not plausible that systematic error of this kind explains the full picture seen here. For instance, comprehensive national assessments have been reported from the 3 countries that were first to implement smoke-free legislation (Ireland, Norway and New Zealand) with remarkably similar findings, which very closely match observations from long running state level evaluations, such as in California.

In many countries there has been a gradual reduction in exposures to SHS over the course of the last decade, or in some instances, longer. This has resulted from a range of tobacco control measures, other than smoke-free legislation, which have contributed to a fall in the prevalence of smoking, a reduction in the average number of cigarettes smoked per day, and changing social norms on smoking in the home. The effects have been substantial; a 20% drop in mean saliva cotinine levels was seen in Northern Ireland in the 12 months prior to smoke-free legislation (Fong *et al.*, 2006). Studies with geographic controls have shown the decline in SHS exposure was even more marked in the presence of legislation. A study in New Zealand used internal controls, measured the change in SHS biomarkers associated with visits to bars in the same study participants (before and after legislation), and reported effects very similar to those observed in times series studies (Fernando *et al.*, 2007). Lastly, the rapidity, consistency, and magnitude of the reduction in SHS exposure associated with legislation all but rule out confounding as an explanation.

The effect of legislation tended to be less noticeable where there were local authority regulations and voluntary restrictions already, as in New York. Improvements in air quality were generally greater in pubs and bars than in other entertainment venues (such as bingo halls and video parlours), though findings varied between studies. For instance, air samples were taken from 31 public premises in Florence and Belluno, Italy and a 77% reduction in $PM_{2.5}$ (0.47 to 0.11 μg/m^3) was found in offices, a 42.5% reduction (0.40 to 0.23 μg/m^3) in industrial premises, a 95% reduction (35.59 to 1.74 μg/m^3) in pubs, and a 94% reduction (127.16 to 7.99 μg/m^3) in discos, two to three months post-legislation (Gasparrini *et al.*, 2006). However, a study in 40 public places in Rome (Valente *et al.*, 2007) found only a 28% reduction in bars (46.8 to 33.7 μg/m^3), and a 16% reduction in fast food restaurants (29.8 to 25.1 μg/m^3) at one year post-legislation. Larger reductions were found in other settings in Rome: a 67% reduction in restaurants (111.0 to 36.5 μg/m^3), a 56% reduction in video game parlours (150.1 to 65.7 μg/m^3), and an 84% reduction in pubs (368.1 to 57.7 μg/m^3). In other countries similar relative changes have been observed (e.g. in Scotland, there was a reduction of 86% in $PM_{2.5}$ readings in bars following the smoking ban) (Semple *et al.*, 2007b). Post-legislation levels of particles in the hospitality venues in Rome were considerably higher than those reported in either Northern Italy or in Ireland and Scotland, but this may reflect variations in background levels of particulate matter from sources other than SHS.

It is important to note the effect of smoking restrictions on inequalities in exposures to SHS in the workplace. Voluntary restrictions were most effective in white collar occupational groups and workplaces with a large number of employees (Pierce *et al.*, 1998a). Comprehensive smoking restrictions have reduced this bias, and therefore have tended to be socially progressive, benefiting particularly disadvantaged groups. In New Zealand a similar effect was noted following the 2004 legislation, when it was apparent that inequalities had been reduced between Maori (the indigenous people) and non-Maori. The post-legislation fall in SHS exposure at work was greater among Maori, since they were over-represented in elements of the work force that were poorly served by voluntary restrictions (Edwards *et al.*, 2008). In the general population, the effect on SHS exposures overall has tended to be greatest among nonsmokers from nonsmoking households (Adda & Cornaglia, 2005; Haw & Gruer, 2007). In the USA, serum cotinine levels of working age adults participating in the US National Health and Nutrition Examination Survey (NHANES) fell by approximately 80% from 1988 to 2002. This was during a period when an increasing proportion of the population was covered by indoor clean air legislation, and the largest reductions occurred in blue collar and service occupations, construction and manufacturing industrial workers, and non-Hispanic black male workers - the groups that historically were most heavily exposed to SHS (Arheart *et al.*, 2008).

The balance of the research to date indicates that legislation restricting smoking in the workplace does *not* lead to increased exposures to SHS in other settings. Studies in New Zealand, Ireland, and Scotland examined contemporaneous changes in smoking in the home, and found no adverse effect of legislation (Akhtar *et al.*, 2007; Haw & Gruer, 2007; Edwards *et al.*, 2008; Hyland *et al.*, 2008b). In Norway, the proportion of households with a total ban on smoking in the home increased from 47%, a year prior to the 2004 comprehensive workplace legislation, to 59% one year later (Lund, 2006). Population data show no sign of "compensating" exposures to SHS resulting from restrictions in the workplace. In the USA, analysis of the long-running NHANES found that amongst individuals residing in counties with extensive smoking restrictions, the upper centiles of urinary cotinine were 80% lower than levels in counties with no restrictions (Arheart *et al.*, 2008). Another analysis of the NHANES data suggested that bans in US bars and restaurants were associated with higher cotinine levels among nonsmokers, possibly due to displacement of smoking to the home (Adda & Cornaglia, 2005). However, the latter study recorded only bans applied at the state level when most legislation in this time period was introduced at the municipality or county level.

In summary, research to date shows substantial reductions in exposure to SHS following legislation to restrict smoking. The size of the effect depends on the nature of the restrictions and the context (including the extent of voluntary restrictions pre-legislation). SHS exposures are not prevented altogether, even with comprehensive legislation, but air quality and biomarker studies indicate that exposures of employees and patrons in what are typically the smokiest workplaces (bars and restaurants) can be cut by 80-90%.

Will these reductions in exposures to SHS be sustained in the long-term? The longest running evaluation studies come from California, and suggest that reductions can be maintained long-term. In California prior to 1995, there were many community level ordinances restricting smoking in public places and work settings, but in that year the California Assembly Bill 13 (AB-13) was implemented, banning smoking in most indoor workplaces. The law was extended in 1998 to cover bars and gaming venues. The proportion of indoor workers in California exposed to SHS fell from 29.1% in 1990 to 11.8% in 1996, and that figure has altered little in subsequent surveys (15.6% in 1999 and 12.0% in 2002) (Gilpin *et al.*, 2003). Elsewhere there have been few opportunities to examine long-term effects. Surveys in New Zealand show that reductions in perceived exposures to smoke in the workplace have remained two years post-legislation (Edwards *et al.*, 2008).

Effects of restrictions in settings other than the workplace

There are a number of residential settings, for example prisons, care homes, and hotel accommodations, which are workplaces for some and homes for others, and for this reason have often been exempted from statutory smoking restrictions.

SHS exposure in prisons is particularly elevated, as smoking rates amongst both inmates and prison guards are high. Indeed, it has been estimated that twice as many prisoners die each year in the USA from SHS as are executed (Butler *et al.*, 2007). Prisons pose a particular challenge for enacting smoke-free policies, as inmates who smoke have few opportunities to do so without exposing others to SHS. By the end of 2007, however, 24 US states had enacted 100% smoke-free policies covering all indoor areas in correctional facilities (Proescholdbell *et al.*, 2008). Though it has been claimed that prisoners commonly continue to smoke in jail, despite bans (Butler *et al.*, 2007), there is evidence that smoking restrictions may be effective. A study of air quality in six North Carolina prisons found that levels of particles fell by 77% after a ban on smoking indoors was implemented (Proescholdbell *et al.*, 2008). A similar study of facilities in Vermont and Massachusetts also reported evidence that bans in prisons substantially reduced levels of SHS in shared areas (Hammond & Emmons, 2005).

A Scottish study has examined levels of SHS exposure in care homes that were exempted from that country's 2006 smoke-free legislation. Data were collected from eight care home establishments in Aberdeen and Aberdeenshire, with a further eight static area measurements made in four designated smoking rooms within these establishments. Assessments were carried out during 2006 using a TSI Sidepak Personal Aerosol Monitor set to sample particulate matter of less than 2.5 microns in size ($PM_{2.5}$) (Semple *et al.*, in press).

Measurements within the four smoking rooms showed very high SHS concentrations with $PM_{2.5}$ concentrations sometimes exceeding 5000 μg/m^3. Time-weighted averages over periods extending to six hours revealed levels ranging between 81 and 910 μg/m^3 (geometric mean value of 360 μg/m^3 from all eight measurements), well in excess of the US Environmental Protection Agency (EPA) hazardous air quality index (250 μg/m^3) for $PM_{2.5}$.

However, employees in the care homes studied did not appear to spend significant time in these environments; therefore, personal exposure levels to SHS were much lower with the geometric mean of the eight work-shift measurements being 24 μg/m^3. Two of the eight (25%) time-weighted average exposures exceeded the US EPA 24 hour air quality index of 65 μg/m^3 (rated as 'unhealthy' for outdoor air). Nevertheless, care home employees' exposures to SHS were on average nearly 10 times lower than those recorded in the hospitality sector in Scotland (before the introduction of smoke-free legislation), where full shift $PM_{2.5}$ levels had a geometric mean value of 202 μg/m^3 (Semple *et al.*, 2007a).

Salivary cotinine data from this group of workers also suggest exposure to SHS at work is much lower than for those in the hospitality trade. The geometric mean salivary cotinine level in nonsmoking care home workers (n=36) was 0.37 ng/ml prior to the smoke-free legislation in March 2006, compared to 2.94 ng/ml in bar employees (Semple *et al.*, 2007b). Nonsmoking care home workers' levels reduced to 0.17 ng/ml after implementation of the legislation (Semple *et al.*, in press). It seems likely that this decrease in salivary cotinine levels was from reduced exposure in social settings outside of work. This data is reflected from a population survey in Scotland, where levels in nonsmoking adults fell by 39% (from 0.43 ng/ml to 0.26 ng/ml) after introduction of the restrictions on smoking in enclosed public places in Scotland (Haw & Gruer, 2007).

Smoking in cars causes high levels of pollution, particularly in the absence of ventilation (average RSP levels of 271 μg/m^3 were measured in driving trials by Rees & Connolly (2006)), and exposure to SHS in this setting is common. In a Canadian survey of youth in grades 5-9, just over a quarter reported they were exposed to smoking while riding in a car at least once in the previous week (Leatherdale *et al.*, 2008). In a New Zealand study, smoking was observed in 4% (95% CI=3.8-4.4) of cars on city roads during the day (and the prevalence was three times higher in areas of high social deprivation) (Martin *et al.*, 2006). In a phone survey in the same country, 71% of current smokers (n=272) reported smoking in their cars (Gillespie *et al.*, 2005). In the United States, surveys have found similar levels of support for smoking bans in cars as in homes (70% and 62% respectively, in a 2005 study of African-American adults) (King *et al.*, 2005). Studies in the USA have found that factors associated with smoking bans in homes, such as education, smoking histories, and ethnicity, tend to also apply to motor vehicles (King *et al.*, 2005; Gonzales *et al.*, 2006). However, those most seriously affected by SHS are often not protected. Exposure to SHS in cars has been reported to increase the rate of wheezing in young people (Sly *et al.*, 2007), but a US survey in 2005 found that only 64% of parents of children with asthma had household smoking bans that included the family car (Halterman *et al.*, 2006).

The only published data available so far on the impact of workplace legislation on smoking in cars comes from Scotland and Ireland. In Scotland, there was no change in reported exposures to SHS in cars, either amongst adults (Haw & Gruer, 2007) or primary school children (Akhtar *et al.*, 2007). The Irish results were similar: the prevalence of private smoke-free cars was reported to be 58% before comprehensive work-place legislation and 55% after (Fong *et al.*, 2006). Legislation that specifically bans smoking in cars with children has been introduced in two Australian states (Tasmania and South Australia) and in California, Arkansas, Louisiana, Maine, Puerto Rico, and Nova Scotia. No studies have yet been published on subsequent changes in exposures to SHS.

With the increasing prevalence of bans on smoking in enclosed public and workplaces, attention has moved to policies covering smoking in outdoor environments (e.g. sports arenas, parks, outdoor dining areas, and beaches) (Chapman, 2007), though there are few studies of exposure to SHS in outdoor settings. Airborne particles were measured in 10 outdoor sites in California, and it was found that during periods of active smoking, peak levels nearby were similar to those observed indoors (Klepeis *et al.*, 2007). Outdoor levels were very sensitive to wind and proximity to smokers, and dropped almost instantly when smoking ceased. Declaration that the 2000 Sydney Olympic Games would be 100% smoke-free was an indication of growing willingness to extend smoking restrictions beyond indoors, however we know of no published studies that have examined the effect of outdoor bans on exposure to SHS.

Effects of smoke-free legislation on population exposure to SHS

Most SHS exposure studies have focused on employees, and, in the case of entertainment and hospitality venues, patrons. However, relatively few studies have examined the impact of legislation on population level exposure to SHS. Data were used from NHANES (1999-2002) to compare the proportion of adult nonsmokers exposed to SHS in counties classified as having extensive smoke-free laws, limited smoke-free laws, and no smoke-free laws (Pickett *et al.*, 2006). SHS exposure was defined as serum cotinine values of ≥0.05 ng/ml (the limit of detection for cotinine assays). The study found that 12.5% of nonsmoking adults living in counties with extensive smoke-free laws were exposed to SHS, compared with 35.1% from counties with limited coverage, and 45.9% from counties with no laws. Men and women from counties with extensive smoke-free laws had 0.1 (95% CI=0.06-0.16) and 0.19 (95% CI=0.11-0.34) the odds, respectively, of SHS exposure, compared with men and women from counties without smoke-free laws.

In an analysis of data from the New York Adult Tobacco Survey (NYATS), it was found that as well as a large reduction in reported SHS exposure in restaurant and bar patrons, geometric mean cotinine fell by 47.4% from 0.078 ng/ml to 0.041 ng/ml (Centers for Disease Control and Prevention, 2007b). The proportion of adults who had no SHS exposure (cotinine <0.05 ng/ml) also increased from 32.5% to 52.4%. However, the very low response rates, both to the survey (22%) and amongst study participants to a request to provide a saliva sample (33%), suggests that the sample may not be representative of the New York population as a whole.

Two Scottish studies of the impact of smoke-free legislation on population exposure achieved more representative samples. The first, a repeat cross-sectional household survey of representative samples of adults aged 18-74 years (Haw & Gruer, 2007), found a 39% reduction in geometric mean cotinine in nonsmokers from 0.57 ng/ml at baseline to 0.26 ng/ml post-legislation, ($p<0.001$). However, only the reduction in mean cotinine concentrations for nonsmokers living in nonsmoking households was significant. For this sub-group, cotinine fell by 49%, from 0.35 ng/ml to 0.18 ng/ml ($p<0.001$). This compares with a non-significant reduction of 16%, from 0.92 ng/ml to 0.81 ng/ml in nonsmokers from smoking households. Reduction in SHS exposure was associated with a reduction in reported SHS exposure in public places (i.e. pubs, other workplaces, and public transport) post-legislation.

The second Scottish study was a repeat cross-sectional school survey of 11 year old children in their last year in primary school (Akhtar *et al.*, 2007). Among nonsmokers, geometric mean salivary cotinine fell from 0.36 ng/ml to 0.22 ng/ml - again a 39% reduction. As in the adult study, significant reductions (51%) in SHS exposure were obtained for children living in households where neither parent smoked. There was also a significant reduction (44%) for children from households where only fathers smoked. For children living in households where either their mother or both parents smoked, mean cotinine fell by only 11%. In combination, the findings from both these studies suggest that the main beneficiaries of the Scottish smoking ban are nonsmokers from nonsmoking households. Indeed, Akhtar and colleagues (2007) conclude that after implementation of the Scottish legislation, nearly one in five Scottish school children are still exposed to SHS at levels (≥1.7 ng/ml) which have been shown to be damaging to arterial health in children (Kallio *et al.*, 2007).

Health impacts of restrictions on smoking in the workplace

Studies of the health effects of smoking restrictions have focused almost exclusively on acute respiratory illness and cardiovascular disease. There is a short lag time between exposure to SHS and onset of symptoms, the evidence that SHS is causally related to these conditions is strong, and the effects are thought to be largely reversible (Chapter 2). SHS also increases the risk of lung cancer, but the time period from exposure to evident disease may be 10-20 years, or longer, making it much more difficult to link changes in disease rates with introduction of smoking restrictions. Nevertheless, given the strength of the evidence linking SHS to increased risk of lung cancer, it is expected that the reduction in exposures following smoke-free legislation will ultimately be reflected in a fall in the incidence of this particular disease.

Studies of those most directly affected by smoke-free legislation have mainly focused on short-term changes in the respiratory health of workers in the hospitality sector. Most studies have measured changes in reported respiratory symptoms (e.g. wheeze and cough) and sensory symptoms (e.g. upper airway and eye irritation); a number have also assessed changes in lung function. The most common measures of lung function are forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC). Some studies have also assessed peak expiratory flow rate (PEF), forced mid-expiratory flow rate (FEF_{25-75}), and total lung capacity (TLC).

A study of a cohort of San Francisco bar workers (Eisner *et al.*, 1998) examined the impact of a smoke-free law on both sensory and respiratory symptoms and lung function. It found a large reduction in reported symptoms and a small, but significant, improvement in lung function following introduction of the smoke-free law. Mean FVC increased by 4.6% post-legislation and mean FEV_1 by 1.2%. Complete elimination of workplace SHS exposure was associated with a 6.8% improvement in FVC and a 4.5% increase in FEV_1, after controlling for smoking status and recent upper and lower respiratory tract infection. A study of Dundee bar workers (Menzies *et al.*, 2006) obtained very similar results to Eisner and colleagues, reporting a reduction in respiratory and sensory symptoms and a 5.1% increase in FEV_1 at two months post-legislation. Interestingly, this study also included measures of pulmonary and systemic inflammation. In asthmatics and rhinitis sufferers (n=23), there was a 20% reduction (p=0.04) in forced expired nitrous oxide (FE_{No}), a marker of pulmonary inflammation, at one and two months post-legislation. A significant reduction was not observed in otherwise healthy bar workers (n=54). For the sample as a whole, however, there was a reduction in markers of systemic inflammation with both total white blood cell (p=0.002) and neutrophil count (p=0.03) falling significantly at two months post-legislation.

In both the San Francisco and Dundee studies follow-up of respondents was two months after implementation. It is not clear what the impact of seasonal factors may be on the US results, but in the case of the Scottish study, temperature differences and differences in rates of respiratory infections between February and May provide an alternative explanation for the improvements in respiratory health. A similar issue arises in interpretation of a Norwegian study of 1525 hospitality workers, of whom 906 were contacted again five months later, following implementation of the national smoke-free legislation. Prevalence of five respiratory symptoms was lower after the legislation than before (Eagan *et al.*, 2006).

A study of staff from Norwegian pubs and restaurants adopted a different approach and assessed cross shift changes in lung function pre- and post-legislation (Skogstad *et al.*, 2006). For the whole sample, there was a reduction in cross shift changes in FEF_{25-75}, which fell from -199 ml/s to -64 ml/s (p=0.01). Significant reductions in cross shift changes in FEV_1 (p=0.03) and in FEF_{25-75} (p=0.01) were also observed in nonsmokers. In asthmatics, there were significant reductions in cross shift changes in FVC (p=0.04), FEV_1 (p=0.02), and FEF_{25-75} (p=0.01). In smokers, only a reduction in cross shift changes in PEF (p=0.02) was observed. Although cross shift changes in lung function fell after the legislation was introduced, with the exception of PEF, absolute values for the other lung function measures were also lower post-legislation. These findings may be explained by the lower mean outdoor temperature of 3°C during the follow-up period compared with 12°C at baseline.

Although there have been many studies on the respiratory health of bar workers, the sample sizes are often small, are drawn from a limited number of locations, and few attempt to eliminate seasonal influences on outcomes or have control groups. Even when studies have controlled for seasonal effects with follow-up at exactly one year after baseline, sample attrition rates have been high at over 40% (Hahn *et al.*, 2006). An exception is a study of the respiratory health of bar workers in the Republic of Ireland (Allwright *et al.*, 2005) who were recruited from three areas in the Republic and one control location in Northern Ireland, where legislation had not yet been introduced. The follow-up rate at one year was 76%. In a sample of nonsmokers (n=158) from the Republic of Ireland, a significant fall in both respiratory (p<0.001) and sensory symptoms (p<0.001) were reported. The reduction in symptoms in this group was accompanied by an 80% reduction in salivary cotinine. By contrast, there was no change in reported symptoms in the control nonsmoking bar workers (n=20) from Northern Ireland, even though there was a 20% reduction in salivary cotinine. A subset of male bar workers from the Republic of Ireland (both smokers and nonsmokers) was tested for changes in lung function. Measurements were taken in a clinical setting. In never smokers, there were small, but significant, increases in predicted FVC, PEV, FEF, and TLC post-legislation. In ex-smokers, there were significant improvements in all measures, except PEF, but no significant changes in lung function measures were observed for smokers (Goodman *et al.*, 2007).

In summary, there is a growing body of evidence on the short-term impact of smoke-free legislation on respiratory health of employees (particularly bar workers). The majority of studies have found an improvement in reported respiratory and sensory symptoms irrespective of follow-up period.

Four studies have also reported small improvements in lung function. Three of the four (which also demonstrated the largest improvements in lung function) did not, however, follow-up study participants a full 12 months after baseline data collection. Therefore, seasonal factors, such as ambient temperature, cannot be ruled out. The fourth study, a study of bar workers from the Republic of Ireland, found statistically significant improvements in lung function in nonsmokers at one year, but these changes were small in absolute terms and it is unclear if they have any immediate clinical significance for respiratory health.

Impact of smoke-free legislation on population health

Cardiovascular health

Most of the studies of the impact of smoke-free legislation on population health have examined the short-term effect of legislation on admissions for acute myocardial infarction and related cardiac conditions. These studies have relied largely on routine hospital data; as a result, they have encountered problems such as inconsistencies in case definition over time and between hospitals, and lack of information in patient level data on smoking status and exposure to SHS.

As previously noted, there is substantial scientific documentation on the acute and longer-term effects of SHS exposure on cardiovascular health, but particular interest in the effects of smoke-free legislation arose after admissions for acute myocardial infarction (AMI) to a single hospital that served Helena, Montana were reduced by 40% (Sargent *et al.*, 2004). This fall occurred in the six months after introduction of smoke-free ordinances and returned to the pre-restriction rate after the ordinances were repealed. Hospital admissions for AMI for a nearby comparison community, where no restrictions had been introduced, showed a slight increase in admissions for the same period. The size of the reduction was surprising and there have been a number of criticisms of the study. The total number of cases observed was small, the statistical approach to analysis did not account for the trend of increasing admissions over time, and the authors did not make any direct observations to confirm that exposure to SHS was reduced during the months when the law was in force.

Since the Montana investigation, another eight published studies have reported reductions in AMI after implementation of smoking bans (Table 6.2, Figure 6.1). Admissions for AMI in Pueblo, Colorado were examined for a three year period between 18 months before and 18 months after smoke-free legislation was introduced (Bartecchi *et al.*, 2006). Hospitalisation rates for patients living within the city limits (where the ordinances applied) were compared with hospitalisation rates for patients residing outside the city limits (controls). Hospital admission rates were also compared with rates for a second external control: a geographically isolated community in El Paso County, Colorado. After smoke-free ordinances were introduced within the city limits, there was a 27% reduction (Rate Ratio (RR)=0.74; 95% CI=0.64-0.86) in AMI in residents residing within the city boundary. A significant reduction was not observed for residents outside the city limits or in the external control.

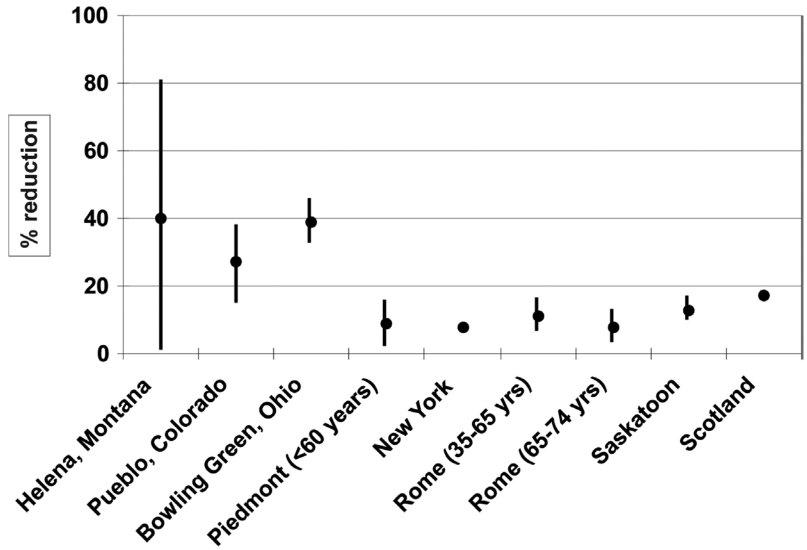

Figure 6.1 Summary of results from studies reporting reduction in hospital admissions for acute myocardial infarction/acute coronary syndrome following implementation of smoke-free legislation

One study has been published that did not detect evidence of a reduction in hospital admissions for acute heart disease (Edwards *et al*, 2008).

A study in Bowling Green, Ohio examined a wider range of hospital admissions (ischaemic heart disease and heart failure) (Khuder *et al.*, 2007). The post-legislation study period began six months after the ban was introduced in order to allow compliance to stabilise. Admissions with a diagnosis of ischaemic heart disease or heart failure fell by 39% (RR=0.61; 95% CI=0.55-0.67) after implementation of legislation. No change was observed in a matched control community from Kent, Ohio.

In a much larger study of admissions for AMI to all hospitals (number of hospitals=261 to 243 over the study period) in New York State, the impact of the 2003 comprehensive smoke-free legislation was examined (Juster *et al.*, 2007). Prior to 2003, there was a patch work of different local laws that had been gradually introduced across the state beginning in 1989. A regression analysis of monthly hospital admissions for AMI against time, suggested an 8% decline attributable to the implementation of a statewide comprehensive ban following after local laws banning smoking. This is less than the effect reported in other US studies, and may be due to the relatively low levels of exposure to SHS in New York State as a consequence of the local ordinances implemented prior to the statewide law.

Table 6.2 Summary of studies on the impact of smoke-free legislation on cardiovascular health

Reference/ location	Control	Study period	Number of cases	Percent reduction (95% CI)	Rate ratio (95% CI)	Data source/end point/ comments
Sargent *et al.*, 2004 Helena, Montana, USA	Patients residing outside Helena	*Pre-ban:* June-Nov1998 *Ban:* 5 June 2002 *Post-ban:* June-Nov 2002	Mean: 40 24	40 (1-79)	0.60 (0.21-0.99)	Hospital admission data/ Acute Myocardial Infarction (ICD9 code: 410)
Barone-Adesi *et al.*, 2006 Piedmont Region, Italy	None	*Pre-ban:* Oct-Dec 2004 versus Oct-Dec 2003 *Ban:* 10 Jan 2005 *Post-ban:* Feb-June 2005 versus Feb-June 2004	3655 3581	< 60 yrs 11 ≥ 60 yrs NS	0.89* (0.81-0.98) 1.05* (1.00-1.11)	Hospital admission data/ Acute Myocardial Infarction (ICD9 code: 410)
Bartecchi *et al.*, 2006 Pueblo, Colorado city limits USA	Pueblo (outside city limit) and El Paso County	*Pre-ban:* Jan 2002-June 2003 *Ban:* 1 July 2003 *Post-ban:* July 2003-Dec 2004	399 291	27 (15-37)	0.74** (0.64-0.86)	Hospital admission data/ Acute Myocardial Infarction (ICD9 code: 410) as primary diagnosis
Juster *et al.*, 2007 New York State, USA	None	*Pre-ban:* Jan 1995-June 2003 *Ban:* 24 July 2003 *Post-ban:* July 2003-Dec 2004	44 000-48 000 per annum	Statewide after local bans: AMI: 8 Statewide without local bans: AMI:19 Stroke: No change		Hospital Admission data/ Acute Myocardial Infarction (ICD9 code: 410); Stroke (ICD9 codes: 430-438)
Khunder *et al.*, 2007 Bowling Green, Ohio USA	Kent, Ohio	*Pre-ban:* Jan 1999-Jan 2002 *Ban:* March 2002; *Post ban:* Jun 2002-Jun 2005	186	To 2003: 39 (33-45) To 2005: 47 (41-55)	To 2003: 0.61 (0.55-0.67) To 2005: 0.53 (0.45-0.59)	Hospitals admission data / Ischemic heart disease; Heart failure (ICD9 codes: 410-14, 428)
Seo & Torabi, 2007 Monroe County, Indiana, USA	Delaware County, Indiana	*Pre-ban:* Aug 2001-May 2003 *Ban:* Most workplaces 1 Aug 2003; Bars from 1 Jan 2005 *Post-ban:* Aug 2003-May 2005	Nonsmokers: 17 Smokers: 8 Nonsmokers: 5 Smokers: 7		Difference nonsmokers: -12 (-21.19 to -2.81) Difference smokers: -1 (-8.59 to -6.59)	Hospital admission data/ Acute Myocardial Infarction (ICD9 code: 410) patients without past cardiac history, hypertension, or high cholesterol

Table 6.2 Summary of studies on the impact of smoke-free legislation on cardiovascular health

Reference/ location	Control	Study period	Number of cases	Percent reduction (95% CI)	Rate ratio (95% CI)	Data source/end point/ comments
Cesaroni *et al*., 2008 Rome, Italy	None	*Pre-ban:* Jan 2000-Dec 2004 *Ban:* 10 Jan 2005 *Post-ban:* Jan-Dec 2005	11 939 2136	35-64 yrs: 11.2 (6.9-15.3) 65-74 yrs: 7.9 (3.4-12.2) 75-84 yrs: NS	0.89† (0.85-0.93) 0.92† (0.88-0.97) 1.02† (0.98-1.07)	Values pre-ban used as reference Hospital admission data Acute Myocardial Infarction (ICD9 code: 410) Acute and sub-acute ischaemic heart disease (ICD9 code: 411)
Edwards *et al*., 2008 Nationwide New Zealand,	None	*Ban*: Dec 2004 Health data for the period 1996-2005 (including 12 months after introduction of ban)		Hospitalisation rates for acute asthma, acute stroke, unstable angina, and exacerbation of chronic obstructive pulmonary disease were lower in the 12 months after implementation of the legislation than in the 12 months before. However, no difference was apparent between these two periods when analysis adjusted for long term trends		Hospital admission data provided by the New Zealand Health Information Service
Lemstra *et al*., 2008 Saskatoon, Canada	None	*Pre-ban:* July 2000-June 2004 *Ban:* 1 July 2004 *Post-ban:* July 2004-June 2005	1377 312	All: 13 (10-16) reduction compared with mean for previous four years	176.1^ (165.3-186.3) 152.4 (135.3-169.3)	Hospital admission data for Acute Myocardial Infarction Note: Very small numbers; overlapping CIs for age adjusted admission rates
Pell *et al*., 2008 Nine Scottish Hospitals UK		*Pre-ban:* June 2005-March 2006 *Ban:* 26 March 2006 *Post-ban:* June 2006-March 2007	3235 2684	All: 17 (16-18) Never smokers: 21 (18-24) Ex-smokers: 19 (17-21) Smokers: 14 (12-16)		Prospective study of all admissions to hospital with acute coronary syndrome (defined as chest pain with a detectable level of cardiac troponin in admission blood sample)

* Age adjusted rate ratio
** Seasonally adjusted rate ratio
† Age adjusted rate ratio, controlling for outdoor PM_{10}, flu epidemic, holidays, and ambient temperature
NS=Statistically, not significant
^=Values reported are age-standardized incidence rates (cases per 100 000 population)

Indeed, the study authors estimate that implementation of the statewide ban without implementation of local laws would have been associated with a 19% reduction in AMI. As with the earlier studies, this one was limited by the absence of individual level data on variables such as occupation and smoking status, and the research design was unable to control for potential time-related confounders, such as long-term trends in smoking prevalence.

In spite of the limitations of these studies, the direction of the findings is consistent. In addition, there are now three large studies from Europe. The first is a study of the impact of the Italian smoking regulations on admission rates for AMI in Piedmont. Admission rates for October-December 2004 (pre-ban) and February-June 2005 (post-ban) were compared with admission rates in the corresponding periods one year earlier. Among men and women under age 60, the admissions for AMI for the period post-ban (February-June 2005) fell by 11% compared with February-June 2004 (RR=0.89; 95% CI=0.81-0.98). The rates of admissions decreased for both men (RR=0.91; 95% CI=0.82-1.01) and women (RR=0.75; 95% CI=0.58–0.96), but notably, no decrease was seen before the ban (comparison of October-December 2004 with October-December 2003). In addition, no decrease was observed in people over 60 years of age (RR=1.05; 95% CI=1.00-1.11). An analysis of hospital data 18 months post-legislation, found there was a cumulative reduction of 9% in hospital admissions for AMI in individuals under age 60 (Barone-Adesi *et al.*, 2006).

A study in Rome also reported a fall in admissions for AMI and acute and sub-acute ischemic heart disease (IHD) in the year following implementation of the Italian smoking ban (Cesaroni *et al.*, 2008). After controlling for outdoor air pollution (PM_{10}), flu epidemic, holidays, and ambient temperature, admissions in 35-64 year old patients fell by 11.2% (RR=0.89; 95% CI=0.85-0.93) and by 7.9% in 65-74 year olds (RR=0.92; 95% CI =0.88-0.97). There was no change in admissions in the oldest group aged 75-84 years. When further terms were included in the analysis for time trends and rates of hospitalisation, the reduction for 35-64 year olds was only marginally significant (RR=0.94; 95% CI =0.89-1.01), with a slightly stronger effect for 65-74 year olds (RR=0.90; 95% CI=0.84-0.94).

The only published study that has so far reported no evidence of effect comes from New Zealand. As part of a national evaluation of the 2004 smoke-free legislation, admission rates for AMI and unstable angina were tracked between 1997 and 2005 for the whole country (Edwards *et al.*, 2008). A comprehensive ban on smoking in the workplace came into force in December 2004. Rates of admission due to AMI increased throughout the study period, counter to the trends in all coronary risk factors (with the exception of obesity), suggesting the increase was more likely due to changes in clinical practice (affecting re-admission rates and recording of diagnoses) than to a change in the underlying incidence of disease. Rates of admission for unstable angina decreased throughout the study period. After adjusting for underlying trends, there was no discernible change in admissions for AMI, unstable angina, or AMI and unstable angina combined, associated with the smoke-free legislation (Edwards *et al.*, 2008). The New Zealand evaluation also analysed hospital admissions for acute asthma, acute stroke, and chronic obstructive pulmonary disease, but again, after adjusting for underlying trends and other potential influences on hospitalisation rates, there was no sign that rates were reduced in the 12 months after implementation of the smoke-free law (Edwards *et al.*, 2008).

Because of the limitations of routine datasets, it is not possible without going back to case notes (as Seo & Torabi, 2007 did in a very small study) to ascertain individuals' smoking status, and thus any observed reductions in AMI admissions could be due to changes in smoking behaviour among smokers, or a reduction in exposure to SHS, or both. To some extent, this was overcome by modelling the impact of the observed reduction in smoking following the introduction of the Italian ban on AMI admissions (Barone-Adesi *et al.*, 2006). It was estimated that the observed reduction in active smoking, after the introduction of the ban, could account for no more than a 0.7% reduction (0.6% among men, 0.9% among women) in admissions for AMI during the study period. Nevertheless, inability to ascertain smoking status (and level of SHS exposure) remains a major problem in interpreting study results in this, and other, time-series analyses.

To surmount the methodological problems associated with post-hoc analysis of routinely collected data, researchers in Scotland carried out a large prospective study of admissions for acute coronary syndrome (ACS) (Pell *et al.*, 2008) as part of a national evaluation of Scotland's smoke-free legislation (Haw *et al.*, 2006). Data on ACS admissions were collected prospectively on all patients admitted with ACS to nine Scottish hospitals over a ten month period prior to the smoke-free legislation (June 2005-March 2006 inclusive) and over the same ten month period following the ban (June 2006-March 2007 inclusive). ACS was defined as chest pain and raised I or T troponins in the admission blood sample. Participating hospitals accounted for 63% of all ACS admissions in Scotland during the pre-legislation period, and 64% post-legislation. Dedicated research nurses identified all eligible patients and completed structured interviews to confirm the diagnosis of ACS, to obtain information on demographic and socioeconomic status, self-reported smoking status, and information on SHS exposure. Blood samples taken on admission were tested for cotinine.

The number of ACS admissions in Scotland fell from 3235 pre-legislation to 2684, a 17% (95% CI=16-18%) reduction. The number of admissions per month fell across the whole period, and the monthly reduction increased with time from implementation of the legislation (chi-square trend, p=0.02). Amongst those admitted with ACS, the number of current smokers fell by 14% (95% CI=12-16%) from 1176 to 1016. There was a 19% (95% CI=17-22%) reduction in ACS admissions among ex-smokers from 953 to 769, and a 21% (95% CI=18-24%) reduction among never smokers from 677 to 537 (Table 6.2). The authors concluded that 56% of the admissions avoided post-legislation were in nonsmokers and never smokers, with a greater reduction among women (28%; 95% CI=23-33%) than men (13%; 95% CI=9-17%).

Following implementation of legislation, the observed drop in admissions was much greater than expected based solely on the underlying trend in ACS admissions. During the preceding 10 years, the fall each year in ACS admissions averaged 3% (95% CI=3-4%) with a maximum reduction of 9% in 2000. The post-legislation fall in admissions was not due to an increase in pre-hospital deaths from ACS. Death certificate data showed there was a 6% decline in pre-hospital deaths due to ACS, from 2202 in 2005/2006 to 2080 in 2006/2007. In England, where legislation had not yet been introduced, there was a 4% reduction in ACS admissions over a similar period.

In summary, the introduction of smoke-free legislation may influence cardiovascular disease by consequent reduction in active smoking (see Chapter 7), or by reduction in exposures to SHS (Dinno & Glantz, 2007). There is strong epidemiological evidence that exposure to SHS is associated with the development of coronary heart disease, and is backed up by experimental and clinical studies of the physiological effects of SHS (Samet, 2006). In smokers, it is estimated that the risk of coronary heart disease is halved one year after quitting smoking. Little research has been conducted to assess the reduction in risk after exposure to SHS has stopped, but current exposure to SHS appears to be more harmful than past exposures. At least one study found that the risk declines as more time elapses since the last exposure (Rosenlund *et al.*, 2001). This finding is consistent with the assumption that the acute effects of SHS exposure on platelet aggregation and epithelial function will be quickly reversed (U.S. Department of Health and Human Services, 2006) and that there is a rapid reversal of epithelial dysfunction when exposure to SHS ceases.

On the basis of what is known about the acute effects of SHS, it follows with a high degree of confidence that a substantial reduction in SHS will cause heart disease rates to fall, assuming there is no change in other risk factors. The magnitude of the reduction in disease due to comprehensive workplace smoking restrictions is less certain. A total of ten studies have now been published, nine reporting reductions in hospital admissions for AMI (six studies), acute coronary syndrome (one study), ischaemic heart disease and heart failure (one study), and AMI and ACS (one study) following implementation of smoke-free legislation. We know of no study reporting negative results (i.e. an absence of an effect of legislation) apart from the New Zealand evaluation. The research reported so far includes only a small fraction of all populations that have implemented state, municipal, or national restrictions on smoking (Chapter 3), raising the possibility that publication and reporting bias may be active. The four studies which found the largest reductions in hospital admissions (along the order of 30%) were based on relatively small populations and included only a small number of admission events. The bigger studies, which covered large geographical areas and included thousands of cases (i.e. Italy, Scotland, and New York State), but did not include control areas, found smaller reductions of between 8% and 17%. This effect size is closer to what one would expect from first epidemiologic principles, based on the change in prevalence of exposure and the strength of the association between SHS and CHD, according to the standard formula for Population Attributable Risk (Population Attributable Risk = Pe (RR-1)/ [Pe (RR-1) + 1], where Pe is prevalence of exposure, RR is relative risk). Applying this formula, if the legislation caused a 40% reduction in population exposure to SHS (as reported in Scotland), and that exposure to SHS increases the risk of CHD by 30% (Chapter 2), then the risk of CHD would be projected to fall by 10.7%.

The Scottish study (Pell *et al.*, 2008) contains the strongest evidence so far of cause and effect. The researchers ascertained the smoking status of patients admitted to the hospital, applied a common diagnostic standard throughout the study period, and found a reduction in rate of hospital admission for ACS in both nonsmokers and smokers alike (although the reduction in admission rates for smokers was smaller). It was possible to relate the change in admission rates to a reduction of nearly 40% in exposure to SHS at a population level in Scotland, all of which adds weight to the argument that the before/after reduction in ACS admissions in nonsmokers can be attributed at least in part to the smoke-free legislation. Since the Scottish legislation was recently introduced (2006), the evaluation thus far includes data for only a short time post-smoking ban, and further follow-up is needed to confirm the reduction in disease burden is sustained.

Epidemiological studies have also established associations between SHS exposure and other conditions, such as chronic respiratory disease and stroke, but to date no study has yet reported a reduction in these conditions following implementation of smoke-free legislation. It will be 10-20 years before the impact of smoke-free laws on lung cancer morbidity and mortality can be assessed.

Summary

In the past, voluntary restrictions on smoking in the workplace have been an important vehicle for reducing exposure to SHS in many countries. However, such restrictions have uneven coverage, and are generally not applied in some of the highest exposure settings (such as bars and gaming venues). Further, they have typically offered little protection for groups in the working population with the poorest health status, and therefore increase the likelihood of widening health inequalities. Comprehensive, mandatory restrictions do not have these shortcomings.

Studies of smoke-free legislation, that prohibits smoking in virtually all indoor workplaces, consistently demonstrate reduced exposure to SHS in high-risk settings by 80-90%. The residual exposures are likely caused by seepage of SHS from smoking around the boundaries of venues, including designated smoking areas on patios and verandas. As a result, indoor smoke-free workplace laws greatly reduce, but do not remove altogether, the potential for harm to health caused by SHS around bars, restaurants, and similar settings.

The most comprehensive study to date indicates that legislation may reduce exposure to SHS population-wide by up to 40%. Several large, well-designed studies have found that comprehensive smoke-free policies do not lead to increased exposure to SHS in the home. Another important feature of comprehensive legislation is its impact on inequalities; the largest absolute reductions in exposure to SHS in the workplace tend to occur among those groups that had the highest pre-legislation exposures.

Given the relatively recent introduction of comprehensive bans, there is only one study reporting on sustained changes in SHS exposure. More than 10 years of follow-up data from California show that the early, large reductions in SHS exposure have been maintained.

There are short-term improvements in health linked to these restrictions on smoking. Workforce studies have reported reductions in acute respiratory illnesses after smoking bans, and early findings of substantial declines in hospital admissions for acute myocardial infarction have been replicated in numerous studies. The literature also indicates that wide-ranging bans on smoking in the workplace are followed by as much as a 10-20% reduction in hospital admissions for acute coronary events in the general population in the first year post-ban. At present, it is not possible to distinguish the contributions to the decline in hospital admissions from changes in smoking behaviour and those of reduced exposures to SHS. The precise magnitude of the reduction in admissions is uncertain, but will vary with the background incidence of heart disease, the prevalence of exposure to SHS preceding the ban, and the extent of the legislation and its implementation.

SHS increases the risk of lung cancer, but the time period from exposure to evident disease may be 10-20 years or longer, making it difficult to link changes in disease rates with introduction of smoking restrictions. However, given the strength of the evidence linking SHS to increased risk of lung cancer, the reduction in exposure following smoke-free legislation is expected to ultimately be reflected in a decrease in the incidence of this particular disease.