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Original Investigation

How smoke-free laws improve air quality: A global study of Irish pubs

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Abstract

Introduction: The present study examined indoor air quality in a global sample of smoke-free and smoking-permitted Irish pubs. We hypothesized that levels of respirable suspended particles, an important marker of secondhand smoke, would be significantly lower in smoke-free Irish pubs than in pubs that allowed smoking.

Methods: Indoor air quality was assessed in 128 Irish pubs in 15 countries between 21 January 2004 and 10 March 2006. Air quality was evaluated using an aerosol monitor, which measures the level of fine particle ($PM_{2.5}$) pollution in the air. A standard measurement protocol was used by data collectors across study sites.

Results: Overall, the level of air pollution inside smoke-free Irish pubs was 93% lower than the level found in pubs where smoking was permitted.

Discussion: Levels of indoor air pollution can be massively reduced by enacting and enforcing smoke-free policies.

Introduction

In recent years, many U.S. states and cities have passed laws prohibiting smoking in workplaces, including pubs and restaurants (American Nonsmokers' Rights Foundation, 2007). Several countries also have enacted comprehensive indoor smoking bans, including Bhutan, Malta, Norway, Sweden, Italy, New Zealand, Uruguay, Scotland, Northern Ireland, and, most recently, England. In March 2004, the government of Ireland banned smoking in all work-sites, including public houses (pubs), making Ireland the first country to implement a nationwide policy. Given the smoking rates in Ireland and the association between smoking and visiting a pub, this was an historic event.

Secondhand smoke (SHS) exposure remains a major global public health concern, and it is entirely preventable (U.S. Department of Health and Human Services [USDHHS], 2000). SHS is a human carcinogen that contains at least 250 chemicals known to be toxic or carcinogenic (National Toxicology Program, 2000). Each year in the United States, SHS is responsible for an estimated 3,000 lung cancer deaths in never-smokers and more than 35,000 deaths from coronary heart disease in never-smokers. Further, SHS causes respiratory infections, asthma, sudden infant death syndrome, and other illnesses in children (Centers for Disease Control and Prevention, 2002; National Toxicology Program, 2000; USDHHS, 2000). SHS exposure in the workplace was responsible for more than 2,800 deaths in nonsmokers in 2002 across the 25 countries of the European Union (Smoke Free Partnership, 2006). The dangers of SHS exposure are highest among restaurant and bar workers, who typically receive little protection from smoking regulations (Eisner, Smith, & Blanc, 1998; Mulcahy & Repace, 2002; Siegel, 1993; Siegel & Skeer, 2003; Skeer & Siegel, 2003; USDHHS, 2000; U.S. Environmental Protection Agency [U.S. EPA], 1992).

SHS is a major source of respirable suspended particles (RSPs) or $PM_{2.5}$ (i.e., particulate matter less than 2.5 microns in diameter). These fine particles are especially dangerous since they can easily be inhaled deep into the lungs and lead to a variety of adverse health effects, including cardiovascular disease, respiratory morbidity, and even death. To protect the public health, the U.S. EPA has set limits of 15 $\mu g/m^3$, for the average annual level of $PM_{2.5}$ exposure, and 35 $\mu g/m^3$, for 24-hr exposure (U.S. EPA Technology Transfer Network, 2006). The 24-hr $PM_{2.5}$ standard was lowered in 2006 (from 65 to 35 $\mu g/m^3$) because mounting evidence established that short-term exposure to $PM_{2.5}$ can result in numerous health effects, including increased mortality (U.S. EPA Technology Transfer Network,

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2006). Studies in the United States have evaluated the impact of smoke-free air legislation by measuring the difference in RSP levels between smoke-free venues and those that permit smoking (Hyland, Travers, & Repace, 2004; Ott, Switzer, & Robinson, 1996; Repace, 2004; Travers et al., 2004).

In the Republic of Ireland, an air quality assessment conducted in Irish pubs showed a dramatic reduction in the presence of RSPs (PM_{10} and $PM_{2.5}$) shortly after implementation of the smoke-free law, with no apparent adverse effects on business (Mulcahy, Byrne, & Ruprecht, 2005; Office of Tobacco Control, 2005). Despite claims that the law would not be adhered to and that it would have a negative impact on pub business, these claims have not been realized. Fong et al. (2006) reported high compliance with the Irish law.

Irish pubs can be found in nearly every city in the world. Some are smoke-free, while others remain smoke-filled. Given the smoke-free legislation in the Republic of Ireland, a study of air pollution in Irish pubs globally provides an opportunity to assess the effectiveness of comprehensive smoke-free laws and policies. The present study examined indoor air quality in a global sample of smoke-free and smoking-permitted Irish pubs. We hypothesized that RSP levels, an important marker of SHS, would be significantly lower in smoke-free Irish pubs than in pubs that allowed smoking.

Methods

Testing sites

Between 21 January 2004 and 10 March 2006, air quality was assessed in 128 Irish pubs in 15 countries. The pubs were located in the Republic of Ireland, the United States, Canada, Australia, Northern Ireland, France, Lebanon, Belgium, Poland, Greece, Germany, China, England, Romania, and Armenia. Testing sites were selected by tobacco control professionals in their respective cities (i.e., a convenience sample). Irish pubs were defined as those that served Irish beer on tap and had an Irish name (e.g., Murphy's, O'Donnell's) or a visible statement that the venue was an Irish pub (e.g., exterior or interior sign with terms such as "Irish pub"). Testing was completed in smoking-permitted and smoke-free pubs on all the days of the week from afternoon onward. Some pubs were individually owned establishments, and some were part of local or national chains.

The smoke-free Irish pubs were located in three cities and one town in the Republic of Ireland (Cork, Dublin, Ennis, and Galway), in two cities in Canada (Toronto and Waterloo), and in nine U.S. cities (Appleton, WI; Austin, TX; Bethesda, MD; Bloomington, IN; Boston, MA; Buffalo, NY; Hartford, CT; Providence, RI; and New York City). Smoking-permitted pubs were located in 13 countries and 38 cities, including Armenia (Yerevan), Australia (Sydney), Northern Ireland (Belfast and Newry), Germany (Berlin), Greece (Athens), Lebanon (Beirut), France (Lyon and Paris), Belgium (Brussels, Charleroi, and Liege), Poland (Torun and Warsaw), China (Beijing), Romania (Bucharest), the United States (Arlington, VA; Atlanta, GA; Baltimore, MD; Chapel Hill, NC; Charleston, SC; Chicago, IL; Denver, CO; Durham, NC; Galveston, TX; Hoboken, NJ; Houston, TX; Indianapolis, IN; Lakewood, OH; Louisville, KY; Manchester, NH; Santa Fe, NM; St. Paul, MN; Philadelphia, PA; Phoenix, AZ; and Washington, DC), and England (London and Manchester).

The average size of the pubs was 961 m^3 (n = 124) with the smoke-free pubs being on average smaller than smoking-permitted pubs (724 vs. 1,069 m^3). The average number of patrons present during sampling was 59 (n = 126) and consistent with their smaller size, the smoke-free pubs had fewer people on average than the smoking-permitted pubs 51 vs. 65.

Measurement protocol

A standard measurement protocol was used by data collectors across study sites. In each establishment, RSPs were measured using a TSI SIDEPAK AM510 Personal Aerosol Monitor (TSI, Inc., St. Paul, MN), an aerosol monitor fitted with a 2.5-µm impactor so that it could measure the concentration of particulate matter with a mass median aerodynamic diameter of less than or equal to 2.5 µm or $PM_{2.5}$. The SIDEPAK was used with a calibration factor setting of 0.32. This factor was determined by calibrating the SIDEPAK with another laser photometer that had been calibrated for SHS and used in previous studies (Repace, 2004). Light scattering photometer devices have proven to be effective air monitoring devices in similar studies (Repace, 2004).

The equipment was set to a 1-min log interval, which averages the previous 60 1-s measurements. Sampling was discreet so that the occupants' normal behavior would not be disrupted. For each pub, the first and last minute of logged data were removed because they are averaged with outdoors and entryway air. The remaining datapoints were averaged to provide an average $PM_{2.5}$ concentration within the venue.

Establishments were tested for a minimum of 30 min. The number of people inside the venue and the number of burning cigarettes were recorded upon entry into the venue and every 15 min during sampling until the venue was exited. Thus, at least three observations were averaged over the time inside the venue to determine the average number of people on the premises and the average number of burning cigarettes. For most establishments, a sonic measure (Zircon Corporation, Campbell, CA) was used to measure room dimensions and, hence, the volume of each of the venues. Room dimensions were estimated when the sonic measure could not be used.

Data analyses

We used the Mann–Whitney *U* test to assess the difference in average $PM_{2.5}$ levels in a cross-sectional sample of smoke-free and smoking-permitted Irish pubs. Descriptive statistics including venue volume, number of patrons, and average smoker density (i.e., number of burning cigarettes per 100 m^3) also are reported for each pub and averaged for all pubs. The active smoker density was calculated by dividing the average number of burning cigarettes by the volume of the room in cubic meters. For smoking-permitted pubs, the bivariate association between active smoker density and $PM_{2.5}$ level was assessed using a Pearson's correlation.

Results

The average $PM_{2.5}$ level in the 41 smoke-free pubs was 23 µg/m^3 (SD = 18.0; range = 3–96 µg/m^3). The average $PM_{2.5}$ level in the 87 smoking pubs was 329 µg/m^3 (SD = 269.7; range = 33–1,320 µg/m^3) (Table 1). Although some overlap in measured exposure was found between smoking-permitted pubs and smoke-free pubs, the average level in all the smoking-permitted pubs was more than 14 times higher than in smoke-free pubs. The level of indoor air pollution was 93% lower in the smoke-free pubs than in those where smoking was permitted. The difference in indoor air quality between smoking-permitted and smoke-free pubs was statistically significant according to the Mann–Whitney *U* test ($p < .001$).

Figure 1 shows the average air pollution levels found in Irish pubs across world regions. The average $PM_{2.5}$ levels in smoke-free Irish pubs in the United States and Canada (14 μg/m^3) and the Republic of Ireland (29 μg/m^3) were significantly lower than levels in smoking-permitted pubs in the United States (263 μg/m^3), other nations (China, Australia, Armenia, and Lebanon; 328 μg/m^3), Northern Ireland (375 μg/m^3), and Europe (474 μg/m^3).

The average smoker density in the smoking permitted pubs ($n = 85$) was 1.40 burning cigarettes/100 m^3. No smoking was observed in any of the pubs with smoke-free policies. As shown in Figure 2, average $PM_{2.5}$ levels were significantly positively correlated ($r = .538$, $p < .01$, $R^2 = .289$) with smoker density.

Discussion

Levels of indoor air pollution can be massively reduced by enacting and enforcing smoke-free policies. Indoor air quality testing revealed that, on average, $PM_{2.5}$ levels in smoke-free Irish pubs were 93% lower than in smoking-permitted Irish pubs (23 vs. 340 μg/m^3). The absence of smokers in the Irish pubs tested also indicates that workplace owners and patrons are complying with these laws.

Some study limitations need to be noted. First, because the sample of pubs tested was a convenience sample, we cannot specifically make inferences to all Irish pubs, although our findings are consistent with other studies that have examined changes in indoor air quality to evaluate the impact of smoking restriction legislation (Hyland et al., 2004; Mulcahy, Evans, Hammond, Repace, & Byrne, 2005; Mulcahy, Byrne, & Ruprecht, 2005; Repace, 2004; Travers et al., 2004). Second, SHS is not the only source of indoor $PM_{2.5}$. Other sources, such as ambient particle concentrations, cooking, and migration of particles from outside, also could contribute to overall levels of indoor air pollution. We would expect, however, that these other sources of air pollution would likely be present in both smoke-free and smoking-permitted pubs; thus, the differences in average $PM_{2.5}$ found are most likely attributable to SHS. Third, testing did not control for ventilation or for smoke that might have migrated from outdoors, where smokers tend to smoke when complying with smoking bans (Mulcahy, Evans, et al., 2005). However, previous research has shown that the ventilation effect is likely to be small and unlikely to account for the large differences observed in smoke-free and smoking-permitted pubs (Repace, 2004).

Despite these limitations, the present study provides evidence that the most effective method for reducing SHS exposure in public places is implementation of policies requiring smoke-free environments (Hopkins et al., 2001). The World Health Organization (WHO) (2006) Framework Convention on Tobacco Control calls on governments to "protect all persons from exposure to tobacco smoke," rather than just specific populations such as children or pregnant women (Guiding Principle 4.1). This protection should be extended, according to Article 8.2, "in indoor workplaces, public transport, indoor public places and … other public places" (WHO, 2006). Since the Republic of Ireland banned indoor smoking in all public spaces, including restaurants and pubs, many countries and U.S. states have implemented policies for smoke-free workplaces, including restaurants and pubs.

Reducing the level of indoor air pollution from SHS should translate into improved health for both workers and patrons. One study found improvements in respiratory health among bartenders after implementation of a statewide smoking ban (Eisner et al., 1998), and another study reported reductions in acute myocardial infarctions in patients admitted to a hospital after implementation of a local smoking ban (Sargent, Shepard, & Glantz, 2004). An examination of SHS exposure among workers following Ireland's comprehensive ban showed significant reductions in air nicotine and salivary cotinine (Mulcahy, Evans, et al., 2005). Respiratory health studies in Ireland have shown results similar to those found in California as well as dramatic reductions in exhaled carbon monoxide and ambient

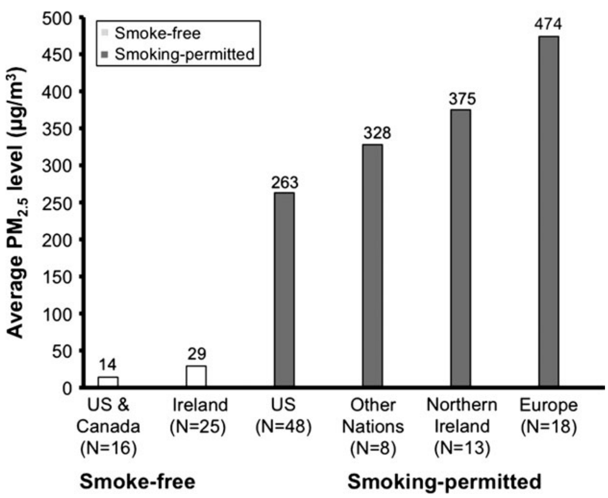

Figure 1. Average level of indoor air pollution in Irish pubs by world region.

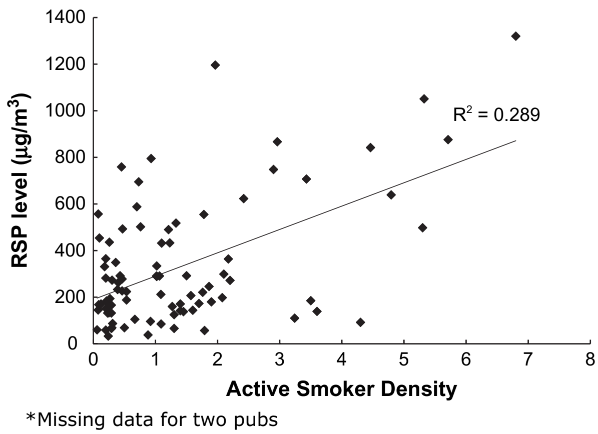

Figure 2. RSP level versus smoker density for smoking pubs.

Table 1. Summary of smoke-free and smoking-permitted pubs by country

Country	State/region	City	Policy	Sample size	Mean $PM_{2.5}$ level ($\mu g/m^3$)
U.S. smoke-free pubs	8	9		14	14
	Connecticut	Hartford	Yes	2	18
	Indiana	Bloomington	Yes	1	10
	Maryland	Bethesda	Yes	1	8
	Massachusetts	Boston	Yes	2	13
	New York	Buffalo	Yes	2	15
		New York City	Yes	2	17
	Rhode Island	Providence	Yes	1	3
	Texas	Austin	Yes	1	22
	Wisconsin	Appleton	Yes	2	17
U.S. smoking pubs	18	20		48	263
	Arizona	Phoenix	No	3	142
	Colorado	Denver	No	4	90
	Georgia	Atlanta	No	2	267
	Illinois	Chicago	No	2	235
	Indiana	Indianapolis	No	3	337
	Kentucky	Louisville	No	5	284
	Maryland	Baltimore	No	1	87
	Minnesota	St. Paul	No	4	276
	New Hampshire	Manchester	No	3	394
	New Jersey	Hoboken	No	2	709
	New Mexico	Santa Fe	No	1	57
	North Carolina	Raleigh–Durham–Chapel Hill	No	2	170
	Ohio	Lakewood	No	3	425
	Pennsylvania	Philadelphia	No	2	293
	South Carolina	Charleston	No	3	236
	Texas	Galveston	No	2	363
		Houston	No	1	125
	Virginia	Arlington	No	3	145
	Washington, DC	Washington, DC	No	2	184
Ireland		4		25	29
		Dublin	Yes	7	30
		Cork	Yes	6	32
		Ennis	Yes	4	32
		Galway	Yes	8	23
Canada		2		2	12
	Ontario	Toronto	Yes	1	19
		Waterloo	Yes	1	4
Other nations		18		39	411
Armenia		Yerevan	No	1	498
Australia	New South Wales	Sydney	No	4	132
Belgium		Brussels	No	1	273
		Charleroi	No	1	876
		Liege	No	2	423
China		Beijing	No	1	145
England		London	No	3	296
		Manchester	No	3	415
France		Paris	No	2	363
		Lyon	No	1	1,051
Germany		Berlin	No	1	278
Greece		Athens	No	1	748
Lebanon		Beirut	No	2	730
Northern Ireland		Belfast	No	7	353
		Newry	No	6	400
Poland		Torun	No	1	695
		Warsaw	No	1	272
		Bucharest	No	1	623
Romania					

benzene levels after the smoking ban (Goodman, Agnew, McCaffrey, Paul, & Clancy, 2007). According to Repace, Al-Delaimy, and Bernert (2006), RSPs are correlated with biological markers for exposure (e.g., nicotine and cotinine) that can be used to predict adverse health outcomes. These results further confirm that these laws, when implemented properly, will reduce SHS exposure and can provide health benefits worldwide.

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Declaration of Interests

None declared.

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