Effects of smoking bans on passive smoking exposure at work and at home. The European Community Respiratory Health Survey

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ABSTRACT

This longitudinal study investigated whether smoking bans influence passive smoking at work and/or at home in the same subjects.

Passive smoking at work and/or at home was investigated in random population samples (European Community Respiratory Health Survey) in 1990-95, with follow-up interviews in 1998-2003 and 2010-2014. National smoking bans were classified as partial (restricted to public workplaces) or global (extended to private workplaces). Multivariable analysis was accomplished by three-level logistic regression models, where level-1, level-2 and level-3 units were respectively questionnaire responses, subjects and centres.

Passive smoking at work was reported by 31.9% in 1990-95, 17.5% in 1998-2003 and 2.5% in 2010-14. Concurrently passive smoking at home decreased from 28.9% to 18.2% and 8.8%. When controlling for sex, age, education, smoking status and ECHRS wave, the odds of passive smoking at work was markedly reduced after global smoking bans (OR=0.45, 95%CI 0.25-0.81), particularly among non-smokers, while the protective effect of global smoking bans on passive smoking at home was only detected in non-smokers.

Smoking bans both in public and private workplaces were effective in reducing passive smoking at work in Europe. However, given the inefficacy of smoking bans in current smokers' dwellings, better strategies are needed to avoid smoking indoors.

Keywords: secondhand smoke; smoking restriction; workplace; home environment; social settings; follow-up study

PRACTICAL IMPLICATIONS

Data from a large multicentre population-based cohort study (the European Community Respiratory Health Survey) were used, involving random samples of 14590 individuals from 13 countries, who were followed-up for about 20 years. Smoking bans across European countries seems to have significantly reduced the occurrence of passive smoking, not only in workplaces but also at home, although to a lower extent. However, these bans apparently failed to reduce passive smoking exposure in current smokers' dwellings, suggesting the need for additional strategies to avoid smoking indoors.

1 | INTRODUCTION

According to the World Health Organization (2005)[1] scientific evidence has unequivocally established that exposure to tobacco smoke causes death, disease and disability. Indeed, exposure to passive smoking accounts for a considerable burden of mortality and morbidity for respiratory diseases[2-5], also in occupational settings.[6] However, there are few data on the course of passive smoking through the last years, and these are likely to have been influenced by smoking bans in public places in different European countries.[7-9]

A national Korean survey found that urine cotinine concentration more than halved among non-smokers from 2009 to 2011 after implementation of stricter smoking regulations.[10] An Irish study showed that salivary cotinine of non-smoking barmen significantly decreased after implementation of total workplace smoking ban.[11] Likewise, a British Survey found an accelerated decline in salivary cotinine levels among nonsmokers after smoke-free legislation was implemented in private and public workplaces in 2007. However, the decline was not observed in lower social classes or in people living with current smokers.[12] Partial restrictions enforced by local governments seem less effective: in a Chinese study[13], smoking restrictions limited to restaurant and bars enforced by the local

Bejing government did not prevent smoking in corresponding non-smoking areas, where significant amount of airborne nicotine could be still detected.

Moreover, information on passive smoking at home is limited: a cross-sectional phone survey in 5 European countries found that the prevalence of passive smoking was larger at home (13-40%) than at the workplace (3-32%).[14]

Smoking bans at workplaces and public spaces may favour voluntary adoption of a smoke-free home, as shown by Polish[15] and German[16] surveys. Nevertheless, a smoking ban at public/work places has also been reported to be ineffective in reducing cotinine levels among children from the poorest UK families[17], and may have displaced smoking from public/work places into the home in China.[18]

The present study reports changes in prevalence and determinants of passive smoking in Europe and Melbourne, Australia, considering smoking bans at the national level[8] and different smoking prevalence within the studied populations.[19] Unlike most other studies we consider passive smoking exposure both at the workplace and at home.

2 | METHODS

2.1 | Study design and study population

The present study was performed in random population samples aged 20-45 years, collected in the frame of ECRHS I in 1990-95 in 27 centres from 13 countries: Iceland, Norway, Sweden, Denmark, Estonia, United Kingdom (Northern Europe according to the United Nations geoscheme [United Nations Statistics Division]); Belgium, Germany, Switzerland, France (Central Europe); Spain, Italia (Southern Europe); Australia. Responders were invited to follow-up interviews in 1998-2003 (ECRHS II) and in 2010-14 (ECRHS III). Passive smoking at home was investigated on the whole sample, while passive smoking at work was investigated among occupationally active individuals.

2.2 | Passive and active smoking exposure

At each wave passive smoking at work was assessed by the question "Do people smoke regularly in the room where you work?". Passive smoking at home was assumed if the participant reported that, not counting him/herself, at least one subject smoked regularly in his/her household. Subjects were also asked "How many hours per day are you exposed to *other people's* tobacco smoke ?" as an attempt to quantify the amount of passive smoking exposure. In addition, in ECRHS II and III subjects were asked to specify the duration of passive smoking according to the setting (home / workplace / bars, restaurants, cinemas or similar social settings / elsewhere).

As regards smoking status, at each wave subjects were classified as: 1) current smokers, if they reported to have smoked at least one cigarette per day or one cigar per week for one year, and also during the last month; 2) past smokers, if they had smoked at least one cigarette per day or one cigar per week for one year, but not in the last month; 3) never smokers, otherwise.

Smoking ban was classified as: 1) absent, if smoking was not forbidden by law in public or private places; 2) partial, when restricted to public places, such as public transport, health facilities and schools; 3) global, when extended to all workplaces (both public and private). Information about specific smoking ban were collected from country-specific legislation. A summary of changes in legislation is presented in the supplementary file (Appendix A).

Occupational status (employed, unemployed, retired) was gathered through the questionnaire. Reported job title, classified as ISCO-88 codes, allowed to define workers concerned with a partial ban as those working in public transportation, health care or education. For ECRHS I, job titles were obtained from the job history collected by ECRHS II questionnaire.

2.3 | Statistical analysis

The influence of sex, age tertile, education (age at completed education <17, 17-20, >20 years), smoking habits (never smokers, past smokers, current smokers), and smoking ban (none, partial, global) on passive smoking exposure at work or at home was evaluated by Fisher's exact test for each wave of ECRHS. Age group based on tertiles were respectively 19.6-29.4, 29.5-37.6, 37.7-50.3 years in ECRHS I, 26.4-38.8, 38.9-46.7, 46.8-56.8 years in ECRHS II, and 38.6-50.1, 50.2-58.1, 58.2-67.8 years in ECRHS III. A subset analysis was made on those reporting jobs in healthcare, education and public transportation in ECRHS I and ECRHS II.

The relation between smoking ban and passive smoking exposure was further investigated by a three-level logistic regression model, where level-1 units (responses to each ECRHS questionnaire) were nested into level-2 units (subjects) which in turn were nested into level-3 units (ECRHS centres).[20] The influence of smoking ban (none/partial/global) on smoking exposure at work (no=0, yes=1) was evaluated controlling for sex, age, education, smoking habits (never/past/current smokers). The same analysis was applied to evaluate the impact of smoking ban on smoking exposure at home (no=0, yes=1). The interaction between public smoking ban and personal smoking habits was also addressed. The intraclass correlation coefficient was reported to express the proportion of residual variance explained by clustering. As a sensitivity analysis, the three-level logistic regression model was repeated among consistent non-smokers at each wave only (7138 workers and 7878 subjects overall). Significance was evaluated by the Likelihood Ratio test or the Wald test and significance level was set at 0.05.

3 | RESULTS

3.1 | Trend in passive smoking exposure

Of the initial sample of 14590 subjects, recruited in ECRHS I, 8573 (58.8%) took part in ECRHS II and 6103 (41.8%) in ECRHS III. Participation to follow-ups was significantly affected by baseline smoking status ($p<0.001$): attendance to ECRHS II and III was lower in current smokers (53.6 and 37.1% respectively) than in never smokers (62.4 and 44.7%) or past smokers (61.1 and 44.5%). Participation to follow-ups was also related to passive exposure to smoking either at work or at home ($p<0.001$): 56.0% and 38.5% of people reporting passive smoking at work in ECRHS I took part in ECRHS II and III respectively, compared to 62.2% and 45.5% of people not reporting this exposure. Similarly, 54.9% and 36.6% of those exposed to passive smoking at home at baseline attended ECRHS II and III respectively, compared to 60.3% and 44.0% of those unexposed.

Passive smoking exposure at work markedly decreased over time, from 31.9% of employed participants in 1990-95, to 17.5% in 1998-2003 and to 2.5% in 2010-14. Similarly, when considering only the 2937 subjects reporting to work in all three surveys, passive smoking at work dropped from 26.8% to 16.0% and further to 2.1% (data not shown). A similar trend was observed in passive smoking in social settings (bars/restaurants/cinemas), which was reported respectively by 8.4% and 1.2% of participants in 1998-2003 and 2010-14. Passive smoking at home also decreased, but to a lower extent (Table 1).

The proportion of past smokers progressively increased during follow-up, while the proportion of current smokers decreased. At baseline, 50% of participants lived in countries without smoking bans, while at the end all participants lived in areas with smoking bans that mostly covered both public and private workplaces (Table 1). Of note, the prevalence of passive smoking exposure, both at work and at home, increased with increasing prevalence of current smokers in the ECRHS cohort in all waves (Supplementary Figure 1).

Not only the prevalence of passive smoking declined, but also the daily duration of exposure. In people reporting passive smoking at home or at work, the median number of daily hours of passive smoking declined from 4 (25^{th}-75^{th} percentiles P_{25}-P_{75} = 2-8) in ECRHS I to 3 (P_{25}-P_{75}=1-7) in ECRHS II and further to 1 (P_{25}-P_{75}=0.5-3) in ECRHS III. The decline was particularly marked at work, where median hours of passive smoking were 3 (P_{25}-P_{75}=1-8) in ECRHS II and 1 (P_{25}-P_{75}=0-4) in ECHRS III, but less marked at home, where median hours of passive smoking amongst those exposed were 2 (P_{25}-P_{75}=1-4) and 1 (P_{25}-P_{75}=0-3) in ECRHS II and III, respectively. On the other hand, no decrease in hours of passive smoking exposure in social settings (bars/restaurants/cinemas) was observed between ECRHS II (1, P_{25}-P_{75}=1-2) and ECRHS III (1, P_{25}-P_{75}= 1-2).

TABLE 1 Main characteristics of the "random sample" participating in the three waves of the European Community Respiratory Health Survey. Categorical variables are reported as absolute frequencies with percent frequencies in parentheses. Age is reported as mean ± SD

	ECRHS I (n=14590)	ECRHS II (n=8573)	ECRHS III (n=6103)
Sex (Women)	7566 (51.9)	4462 (52.0)	3194 (52.3)
Age (years) [a]	33.5 ± 7.2	42.7 ± 7.1	54.1 ± 7.1
Age at completing education [b]			
<17 years	2594 (21.1)	1492 (18.7)	778 (16.3)
17-20 years	5106 (41.5)	2865 (35.9)	1678 (35.1)
>20 years	4595 (37.4)	3625 (45.4)	2324 (48.6)
Smoking habits [c]			
Never smoker	6048 (41,5)	3700 (43.3)	2692 (44.4)
Past smoker	2996 (20.6)	2341 (27.4)	2202 (36.3)
Current smoker	5518 (37.9)	2500 (29.3)	1171 (19.3)
Passive smoking at home [d]	4204 (28.9)	1547 (18.2)	521 (8.8)
Passive smoking at work [e]	3590 (31.9)	1271 (17.5)	111 (2.5)
Passive smoking in social settings [f]	------	697 (8.4%)	72 (1.2%)
Occupational status [g]			
Employed	11328 (78.1)	7305 (85.5)	4588 (75.7)
Student	1268 (8.7)	86 (1.0)	23 (0.4)
Unemployed	1917 (13.2)	1070 (12.5)	577 (9.5)
Retired	------	81 (0.9)	870 (14.4)
Smoking ban:			

No	7363 (50.5)	3708 (43.3)	-------
Partial	4536 (31.1)	2826 (33.0)	1861 (30.5)
Global	2691 (18.4)	2039 (23.8)	4242 (69.5)

[a] Information on age in ECRHS I was missing in 70 subjects.

[b] Information on education in ECRHS I, ECRHS II and ECRHS III was missing in 2295, 591 and 1323 subjects respectively.

[c] Information on smoking habits in ECRHS I, ECRHS II and ECRHS III was missing in 28, 32 and 38 subjects respectively.

[d] Information on passive smoking at home in ECRHS I, ECRHS II, ECRHS III was missing in 55, 55, 153 subjects respectively.

[e] Percentages were computed on people currently working in ECRHS I (n=11328), II (n=7305) and III (n=4588). Information on passive smoking at work in ECRHS I, ECRHS II, ECRHS III was missing in 63, 36 and 100 subjects respectively.

[f] Information on passive smoking in social settings was not collected in ECRHS I. In ECRHS II and ECRHS III the information was missing in 250 and 215 subjects respectively.

[g] Information on occupational status in ECRHS I, ECRHS II and ECRHS III was missing respectively in 77, 31 and 45 subjects.

3.2 | Trends in passive smoking exposure at work by country

In the 1990s, passive smoking at work was rarely reported in Sweden (11.2%) and Australia (14.1%), whereas about half of workers in Southern Europe (Spain 54.7%; Italy 46.0%) reported being exposed. After two decades the prevalence of passive smoking had considerably declined in all countries, becoming lower than 2.5% in Northern Europe, Australia and several countries in Central Europe; of note, passive smoking at work has nearly disappeared in Sweden, France, Iceland and Norway (Figure 1).

The declining trend largely reflected the introduction of smoking bans in different countries· At baseline, (i.e. before ECRHS I) smoking bans both in public and private workplaces were already present in Norway and Sweden, whereas smoking bans in public workplaces were present in Denmark, Belgium, France and Italy. Between ECRHS I and II, the smoking ban in Denmark was extended to private workplaces, while smoking ban in public areas was introduced in Australia· Finally, between ECRHS II and III, smoking was forbidden in all workplaces in UK, Belgium, France, Spain and Italy, and in public workplaces in Iceland, Estonia, Germany and Switzerland.

3.3 | Determinants of passive smoking exposure: Univariable analysis

In all the three waves of the ECRHS male sex, current smoking, shorter education, living in a country with no/partial smoking ban were associated with passive smoking at work. Older workers less frequently reported passive smoking in ECRHS I and III (Table 2).

Workers employed in public transports, hospitals and schools were less exposed to passive smoking at work than the other workers, both in ECRHS I (16.4% vs 29.9%) and in ECRHS II (11.8% vs 18.6%) ($p<0.001$). As expected, partial ban was associated with a decrease in passive smoking exposure compared to no ban among the former workers (from 24.3% to 14.5% in ECRHS I) but not among the latter workers (from 32.85% to 35.7%),

whose passive smoking exposure decreased only in the presence of a global ban (17.4%). The difference was particularly pronounced in countries with a partial smoking ban, where only 14.5% of people working in these sectors were exposed to passive smoking at work in ECRHS I versus 35.7% of the other workers.

Lower education, current smoking and living in a country with no/partial ban were associated with passive smoking not only at the workplace but also at home. Likewise, older participants were less exposed to passive smoking at home in ECRHS I and III. Contrary to passive smoking at work, passive smoking at home was more frequently reported by women (Table 3).

TABLE 2 Exposure to passive smoking at work as a function of demographic/lifestyle characteristics in randomly selected subjects who reported to work in the three waves of the European Community Respiratory Health Survey. Numbers are percentages of exposure and the ratio of exposed to responders is reported in parentheses

	ECRHS I (n=11328)	ECRHS II (n=7305)	ECRHS III (n=4588)
Sex			
Men	35.1 (2059/5865)	19.9 (745/3742)	3.3 (74/2256)
Women	28.4 (1531/5400)	14.9 (526/3527)	1.7 (37/2232)
	p<0.001	p<0.001	p<0.001
Age [a]			
1st tertile	35.7 (1337/3746)	18.4 (445/2420)	3.0 (45/1493)
2nd tertile	31.7 (1183/3732)	16.9 (410/2425)	2.7 (41/1492)
3rd tertile	28.3 (1056/3736)	17.2 (416/2424)	1.7 (25/1503)
	p<0.001	p=0.352	p=0.035
Age at completing education [b]			
<17 years	39.5 (788/1994)	25.8 (286/1107)	5.2 (21/406)
17-20 years	34.6 (1515/4381)	21.3 (525/2464)	2.9 (35/1219)
>20 years	25.6 (1039/4055)	13.3 (425/3197)	1.1 (21/1880)
	p<0.001	p<0.001	p<0.001
Smoking habits [c]			
Never smoker	23.8 (1071/4505)	11.8 (372/3143)	1.3 (27/2022)
Past smoker	25.9 (639/2470)	14.5 (294/2022)	1.9 (30/1597)
Current smoker	43.9 (1877/4274)	28.9 (603/2089)	6.4 (54/847)
	p<0.001	p<0.001	p<0.001

Smoking ban:			
No	34.8 (1924/5525)	22.9 (710/3100)	-------
Partial	35.6 (1253/3524)	17.8 (424/2377)	3.5 (52/1481)
Global	18.6 (413/2216)	7.6 (137/1792)	2.0 (59/3007)
	p<0.001	p<0.001	P=0.002

Information on passive smoking at work in ECRHS I, ECRHS II, ECRHS III was missing in 63, 36 and 100 subjects respectively. *P*-values were computed by Fisher's exact test.

[a] Information on age in ECRHS I was missing in 52 subjects.

[b] Information on education in ECRHS I, ECRHS II and ECRHS III was missing in 837, 503 and 996 subjects respectively.

[c] Information on smoking habits in ECRHS I, ECRHS II and ECRHS III was missing in 17, 17 and 24 subjects respectively.

TABLE 3 Exposure to passive smoking at home as a function of demographic/lifestyle characteristics in randomly selected subjects participating in the three waves of the European Community Respiratory Health Survey. Numbers are percentages of exposure and the ratio of exposed to responders is reported in parentheses

	ECRHS I (n=14,590)	ECRHS II (n=8,573)	ECRHS III (n=6,103)
Sex			
Men	26.9 (1881/6995)	17.0 (695/4084)	8.2 (234/2861)
Women	30.8 (2323/7540)	19.2 (852/4434)	9.3 (287/3089)
	p<0.001	p=0.009	p=0.130
Age			
1st tertile	32.5 (1556/4824)	18.1 (513/2838)	9.1 (180/1982)
2nd tertile	27.9 (1343/4819)	17.1 (486/2838)	10.2 (203/1981)
3rd tertile	26.5 (1280/4824)	19.3 (548/2842)	6.9 (138/1987)
	p<0.001	p=0.108	p=0.001
Age at completing education			
<17 years	36.9 (952/2581)	27.3 (405/1486)	13.7 (101/738)
17-20 years	31.1 (1586/5097)	20.0 (571/2852)	9.3 (153/1644)
>20 years	23.4 (1071/4578)	13.8 (499/3603)	6.9 (157/2274)
	p<0.001	p<0.001	p<0.001
Smoking habits:			
Never smoker	19.0 (1143/6024)	10.3 (379/3670)	4.3 (112/2626)
Past smoker	20.0 (597/2992)	13.0 (304/2336)	5.9 (127/2167)
Current smoker	44.8 (2464/5498)	34.6 (862/2494)	24.7 (279/1131)
	p<0.001	p<0.001	p<0.001

Smoking ban:			
No	31.0 (2273/7332)	23.3 (860/3695)	-------
Partial	29.4 (1327/4520)	17.0 (478/2815)	8.3 (150/1814)
Global	22.5 (604/2683)	10.4 (209/2008)	9.0 (371/4136)
	p<0.001	p<0.001	P=0.397

Information on missing data are reported in the footnotes of Table 1.

P-values were computed by Fisher's exact test.

3.4 | Determinants of passive smoking exposure: Multivariable analysis

In multivariable analysis the odds of passive smoke exposure at work was significantly lower in women, in older workers and in workers with longer education. At the individual level, current smoking more than doubled the risk of passive smoking at work (OR=2.86, 95%CI 2.54-3.22), while past smoking had minor although significant effects (OR=1.32, 95%CI 1.16-1.51). Passive smoking at work was dramatically reduced by smoking bans, but only if smoking restriction was extended to both public and private workplaces (OR=0.45, 95%CI 0.25-0.81), while smoking bans restricted to public places apparently had no effect (OR=1.23, 95%CI 0.81-1.88).

The effect of smoking ban was modified by smoking habits (p<0.001): global smoking ban reduced by 75% smoking exposure at work among never smokers and past smokers, while the risk reduction among current smokers was less pronounced and non significant (Figure 2). Taking as reference areas without smoking restrictions, the ORs of passive smoking exposure after a global smoking ban were respectively 0.27 (95%CI 0.15-0.51) among never smokers, 0.39 (95%CI 0.21-0.73) among past smokers and 0.64 (95%CI 0.35-1.16) among current smokers. In the final model with the interaction between smoking ban

and smoking habits, centre explained 10.8% of residual variance according to the intraclass correlation coefficient, while subjects, nested within centre, explained an additional 41.5%.

As already observed for passive smoking at work, older age or higher education were associated with lower risk of passive smoking also at home. Remarkable differences between the two types of exposure were sex, as men had a higher risk of being exposed to passive smoking at work while women had a higher risk at home. The impact of global smoking bans on passive smoking at home was smaller although significant among never and past smokers, while no effect was detected among current smokers. Taking as reference subjects living in countries without smoking restrictions, the ORs of passive smoking exposure at home after a global smoking ban were respectively 0.47 (95%CI=0.31-0.72) among never smokers, 0.48 (95%CI=0.31-0.74) among past smokers and 1.04 (95%CI=0.70-1.52) among current smokers. As a consequence, the interaction between smoking ban and smoking habits was highly significant ($p<0.001$). In the final model with the interaction between smoking ban and smoking habits, centre explained only 3.7% of residual variance according to the intraclass correlation coefficient, while subjects, nested within centre, explained as much as 58.6%.

As shown in the supplementary Tables 1 and 2, the results did not change either for ETS at work or at home, when multivariable analysis was accomplished on subjects who consistently declared to be non-smokers at each ECRHS wave.

4 | DISCUSSION

The main results of the present study are:

1. Passive smoking at work dramatically decreased in all centres participating in ECRHS during a 20 years follow-up. As a consequence, the large differences observed between Northern and Southern Europe in the 1990s narrowed down in the last decade.

2. At the individual level, being a male, lower education and being a current smoker were risk factors for passive smoking at work. As expected, passive smoking was higher in centres with higher smoking prevalence.

3. Smoking ban at the national level was a strong predictor of lower exposure to passive smoking at work, although this was effective only when extended to both public and private workplaces. The effect of global smoking bans in the workplace was particularly pronounced and significant among workers who had never smoked or had stopped smoking.

4. The proportion of people reporting passive smoking at home significantly declined during the 20 years follow-up, but this trend was less pronounced than the trend observed at work. Moreover smoking bans, including global smoking bans, were unrelated to passive smoking in current smokers' dwellings.

Passive smoking at work significantly declined in most European countries and Australia during the last 25 years, being reported by only 2.5% of workers in 2010-14. Hence, antismoking campaigns and smoking bans at the workplace seem to have been effective in reducing passive smoking. In comparison, the Eurobarometer survey, performed in 2012, found a 10 times higher prevalence of passive smoking exposure at workplace (24.4%) among non-smokers. The difference could be attributed, at least in part, to differences in countries involved and in the definition of passive smoking, as the Eurobarometer included also Eastern European countries and used a wider definition of passive smoking, also comprising "occasionally exposure".[21] Importantly, a higher prevalence of passive smoking exposure has been recorded in Eastern European countries compared to Western Europe, both at home and elsewhere, and this result was confirmed by urinary cotinine.[22]

Of note, the decline in passive smoking exposure was observed also in social settings, where smokers are the main source of fine particulate matter.[23]

The presence of a complete smoking-ban strongly reduced passive smoking at work in never smokers and past-smokers, in agreement with a recent Cochrane Systematic Review, where the introduction of a smoking ban reduced the rate of passive smoking exposure in particular occupational settings (hospitals and prisons).[24]

Differently from a complete ban, a smoking ban restricted to public places (health care settings, public transportations and educational facilities) did not have any impact on the declining trend in passive smoking exposure at work or at home. This lack of effectiveness could be mainly attributed to the rather small proportion of workers subject to this restriction (for example, in ECRHS II sample around 15%), but also to high levels of tobacco smoke exposure in outdoor spaces[25], or to variable compliance to smoking-bans in different countries.[8] Anyway, this result was not unexpected as only total bans work well and comply with the WHO Framework Convention on Tobacco Control (FCTC) and Council Recommendation on Smoke Free environments.[9]

The effect of smoking bans on passive smoking exposure was strongly modulated by individual smoking habits. When smoking was forbidden in all workplaces, the risk of passive smoking at work became less than one third among never smokers, was more than halved among past smokers and reduced by only one third among current smokers. This could reflect the tendency to create restricted smoking areas outside the workplace, where workers could smoke together with other smokers.[26]

Low education attainment, and current smoking status were predictors of passive smoking at home, in agreement with previous studies.[15] Younger age predicted also home-related passive smoking, whereas male gender, a risk factor for work-related passive smoking, turned out to be protective against home-related smoke exposure. Smoking ban at work indirectly reduced passive smoking also at home, but only among never and past smokers and with a smaller protective effect. Other previous studies have highlighted the

concept that working in a tobacco-free environment is associated to living in a smoke-free house.[27] Anti-smoking campaigns should also focus on current smokers, warning them that if they must smoke, they shoud not smoke indoors.

4.1 | Strengths and limitations

The present study had several strengths. The same validated questionnaires were used in the three surveys. The study base was a random sample from the adult general population and its size was relatively large (n=14590 in ECRHS I), enabling generalizability of the results and robust statistical analyses to be performed, based on three-level models. A sensitivity analysis, performed on consistent non-smokers at all ECRHS waves, confirmed the protective effect of smoking bans, ruling out a possible confounding bias due to possible collinearities between current and passive smoking.

Also some limitations must be acknowledged. Participation at follow-up was lower in subjects reporting passive smoking exposure at home or at work at baseline, and this selection bias could have led to underestimate passive smoking prevalence at follow-up, thus amplifying the declining trend in passive smoking. Second, smoking habits and passive smoking were assessed only by questionnaire. Anyway, in one centre (Verona) a good agreement (Cohen's kappa coefficient of agreement=0.93) was found between ECHRS I questionnaire and serum cotinine levels; in addition, among non-smokers a significant linear association (coefficient of determination R^2=0.136) was observed between serum cotinine levels and daily hours of passive smoking.[28] Finally, we had complete data on the occupational status (employed, unemployed and retired), but detailed data on occupational history were partially missing for ECRHS I and ECRHS III. This partially limited the linkage between the smoking ban and the specific occupation held at the time of the survey.

5 | CONCLUSIONS

In conclusion, smoking bans across European countries and Australia seem to have significantly reduced the occurrence of passive smoking, especially in workplaces and among non-smokers. To be effective, smoking ban should concern not only public workplaces, such as school, hospital and public transport, but should be applied also to private workplaces. Passive smoking exposure was assessed also at home in the same cohort. Smoking ban indirectly reduced passive smoking exposure also in private dwellings, but not in current smokers' houses, suggesting that the effect of smoking bans is strongly influenced by individual health behaviour toward smoking. This finding emphasizes the importance of implementing smoking cessation policies, in order to reduce also the burden of secondhand smoke.

Conflict of interest statement

Dr. Angelo Corsico reports grants from Chiesi Farmaceutici and from GlaxoSmithKline Italy during the conduct of the study. Dr. Pascal Demoly reports personal fees as speaker bureau for ALK, STGGR, MYLAN, and Board of TFS, Chiesi. Dr. Rain Jõgi reports grants from Estonian Research Council Personal Research (Grant no 562) during the conduct of the study, and personal fees for consultancy, lectures and meeting expenses from GSK, Boehringer, Novartis outside the submitted work. Dr. Isabelle Pin reports personal fees and presentation/travel grants from Astra Zeneca and travel grants from Novartis, outside the submitted work. Dr. Deborah Jarvis reports grants from MRC during the conduct of the study. Dr. Murgia reports grants, personal fees and non-financial support from Chiesi Farmaceutici, non-financial support from GSK, non-financial support from Novartis and TEVA, personal fees from Menarini, outside the submitted work. Dr. Verlato reports non-

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Supplementary data

Supplementary material related to this article (Appendix A, Supplementary Figure 1, Supplementary Tables 1 and 2) can be found in the online version.

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FIGURE CAPTIONS

FIGURE 1 Trend of passive smoking at work in different countries

FIGURE 2 Influence of sex, age, education, smoking behaviour, and smoking ban on the risk of tobacco smoke exposure at work in the three waves of ECRHS. Longitudinal data were evaluated by a three-level logistic regression model, where level-1 units (responses to each ECRHS questionnaire) were nested into level-2 units (subjects) which in turn were nested into level-3 units (ECRHS centres).·Columns are ORs reported on a logarithmic scale, while bars are 95% confidence intervals. Grid columns = no ban, dashed columns = partial ban, dotted areas = global ban·

FIGURE 3 Influence of sex, age, education, smoking behaviour, and smoking ban, and centre-specific smoking prevalence on the risk of tobacco smoke exposure at home in the three waves of ECRHS. Longitudinal data were evaluated by a logistic regression model, where level-1 units (responses to each ECRHS questionnaire) were nested into level-2 units (subjects) which in turn were nested into level-3 units (ECRHS centres). Columns are ORs reported on a logarithmic scale, while bars are 95% confidence intervals.
Grid columns = no ban, dashed columns = partial ban, dotted areas = global ban.