

The effect of environmental tobacco smoke exposure on allergic sensitization and allergic rhinitis in adults

Abstract Background: There is only little and furthermore conflicting knowledge about the relationship between passive smoking and allergy in adults. In this work, we assess the association between exposure to environmental tobacco smoke (ETS) at home or at work, and allergic sensitization and allergic rhinitis in 4093 German adults. Methods: Our study population comes from the German National Health Survey 1998 of which we analyzed 4093 adults (17–79 years) being non-smokers and having complete information on passive smoking and allergy. The association between ETS exposure and allergic sensitization and allergic rhinitis was assessed using logistic regression models.

Results: The effect of ETS exposure on allergic sensitization was biggest at the workplace [adjusted OR = 1.17 (0.97, 1.41)]; the same could be observed with respect to allergic rhinitis [adjusted OR = 1.20 (0.96, 1.51)]. There was no effect of ETS exposure at home on both allergic sensitization [adjusted OR = 0.99 (0.76, 1.29)] and allergic rhinitis [adjusted OR = 1.05 (0.76, 1.43)] in our analysis. Conclusions: The findings from our study show a statistically non-significant tendency that exposure to ETS at the workplace increases allergic sensitization and allergic rhinitis in adults. This tendency could not be observed with respect to ETS exposure at home.

**R. Topp¹, W. Thefeld²
H.-E. Wichmann^{1,3}, J. Heinrich¹**

¹GSF – National Research Center for Environment and Health, Institute of Epidemiology, Ingolstaedter Landstraße 1, Neuherberg, Germany, ²Robert Koch Institute, Berlin, Germany, ³Chair of Epidemiology, Ludwig-Maximilians University of Munich, Neuherberg, Germany

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Joachim Heinrich
GSF-Institute of Epidemiology,
85764 Neuherberg, Germany
Tel.: +49 89 3187 4150
Fax: +49 89 3187 3380
e-mail: joachim.heinrich@gsf.de

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Practical Implications

Exposure to ETS at the workplace should be minimized in order to reduce the risk of allergic sensitization, and allergic rhinitis.

Introduction

Environmental tobacco smoke (ETS) has been classified as a human carcinogen (MAK-Commission, 1998; Wichmann et al., 1999) and is known to be an important risk factor for several health problems (World Health Organization, Regional Office for Europe, 2000), among them the development of atopy and increased total IgE concentrations. ETS is a mixture of cigarette sidestream smoke (SS) and mainstream smoke (MS). ETS contains about 85% SS, the smoke curling between puffs off the end of a lit cigarette, and 15% of MS, the smoke first inhaled by an active smoker and then exhaled into the environment (Witschi et al., 1997). SS is generated at lower burning temperatures than is MS and has a different chemical composition than has MS. In particular, SS is

richer in certain carcinogens and also undergoes rapid aging, a process that changes its physico-chemical properties (Johnson et al., 1990).

Because cigarette smoke is a complex mixture of particulate and gaseous components containing over 4000 different chemical compounds many of which exhibit biotoxicity (Hoffmann and Wynder, 1986; MAK-Commission, 1998; United States Environmental Protection Agency, 1992), it is difficult to assess the effects of each individual constituent on human health. Nevertheless, chronic inhalation of cigarette smoke has been shown to alter a wide range of immunologic functions in humans and animals and may adversely affect both humoral and cell-mediated immune responses (Geng et al., 1996). It is assumed that ETS acts not as an allergen but rather as an adjuvant which facilitates sensitization, but the mechanism is still not

fully understood. ETS may damage the respiratory epithelium, and this damage may itself increase the likelihood that allergens will reach immunoreactive cells (Wjst et al., 1994). Furthermore, tobacco smoke may have a direct immunomodulating effect, possibly initiated already prenatally *in utero* (Halcken et al., 1995). Studies by Zetterström et al. (1985) in rats suggest that for allergic sensitization to occur, a direct contact between the allergen and the bronchial mucosa is necessary. This would support the hypothesis that a disruption of the bronchial epithelium by tobacco smoke with increased permeability to antigens may be involved. It is also possible, however, that the disruption of the epithelium seen in animal models of tobacco smoke inhalation may be the consequence of an inflammatory process occurring in the mucosa, which may also alter the mechanisms by which the aeroallergens are handled and presented to immunocompetent cells in the lung (Ronchetti et al., 1992).

Investigations on the effect of ETS have been carried out using both murine models as well as human studies. The impact of ETS on the immune system of mice is well established: second-hand smoke exacerbates the immune response of mice exposed to an allergen (Rumold et al., 2001; Seymour et al., 1997). The effect of passive exposure to tobacco smoke on humans is less clear. There have been works showing an association between ETS exposure and allergic sensitization when studying children exposed to parental tobacco smoke both pre- and postnatally (Atici et al., 1994; El-Nawawy et al., 1996; Magnusson, 1986; Wolf-Ostermann et al., 1995). On the other hand, there have been also several studies failing to show an association between passive smoking and enhanced allergic sensitization in children (Hjern et al., 2001; Kulig et al., 1999; Ownby and McCullough, 1988; Soyseth et al., 1995; Tariq et al., 2000). A systematic review of the effects of parental smoking on IgE levels, skin prick positivity, and allergic rhinitis or eczema in children was carried out by Strachan and Cook (1998). For each outcome they found studies both confirming and failing to show a significant effect resulting in a balance of evidence. Statements of expert committees are also conflicting: while the German MAK commission concludes that the frequency of allergic rhinitis was not increased after ETS exposure (MAK-Commission, 1998), the World Health Organizations reports that ETS influences the development of atopy and increases total IgE (World Health Organization, Regional Office for Europe, 2000).

Studies investigating the effect of ETS on allergy in adults are rare and do also not show consistent findings. Cummings et al. (1991) demonstrated that in healthy non-smokers and those with pre-existing respiratory disease, exposure to ETS is a common source of acute irritation to the eyes, upper respiratory tract, and to a lesser extent the lower respiratory tract. Oryszczyn et al. (2000) found an increase of total IgE

in relatives of asthmatics but not in control subjects when exposed to ETS. In contrast, Janson et al. (2001) found no significant association between any type of passive smoking and total serum IgE.

Another point of controversial discussion is the role of gender in the sensitization process induced by ETS. In a murine model, Seymour et al. (2002) found highest IgE concentration for the combination of female gender and ETS exposure. In humans, results are varying. Some studies showed a trend for increased allergic reactions in boys compared with girls when exposed to ETS (Martinez et al., 1988; Ronchetti et al., 1990, 1992) and others found this trend rather for females than for males (Oryszczyn et al., 2000).

In the present study, we assessed the association between exposure to ETS at home or at work, and allergic sensitization and allergic rhinitis/conjunctivitis in a large random population sample of 4093 German adults. Additionally, we carried out a subgroup analysis investigating if there was any effect of gender and asthmatic history on the relationship between ETS exposure and the mentioned health outcomes.

Material and methods

This is a cross-sectional study investing the relationship between passive smoking and allergic rhinitis/conjunctivitis and atopy using data from the German National Health Interview and Examination Survey 1998.

Study population

Between October 1997 and March 1999 the German National Health Survey investigated 7124 subjects aged 17–79 years from a population-based sample which is representative with respect to age, gender and community size with an oversampling of the general population in the East German area. Methods and population selection are described in detail elsewhere (Bellach et al., 1998; Thefeld et al., 1999).

In our analysis only non-smokers were considered ($n = 4829$, 67.8%). Data on passive smoking, allergic rhinitis/conjunctivitis or atopy were missing for 736 of these. Thus, our final study population consisted of 4093 subjects.

We analyzed self-administered questionnaire-based data from the public use file BGS98 which was provided by the Robert Koch Institute, Berlin, Germany. Moreover, a screening test for allergic sensitization against common aero-allergens (SX₁) was performed in the subjects' sera (details are mentioned below).

Data on allergic rhinitis/conjunctivitis, asthma, passive smoking and confounders

For the assessment of allergic rhinitis/conjunctivitis we used data from the question 'Which of the following

diseases have you ever had?' and the answering category 'Hay fever, allergic conjunctivitis'.

For the assessment of passive smoking we used data from the question 'During the day or in the evening, do you frequently stay in rooms where people smoke?' and the answering categories 'At work' and 'At home' (multiple responses were allowed).

For the subgroup analysis where we stratified for asthmatic history, we used data from the question 'Which of the following diseases have you ever had?' and the answering category 'Asthma bronchiale, allergic asthma'.

Furthermore, we used data on gender, age, number of siblings, residential region, community size and social status (social index by Winkler and Stolzenberg (1999)).

Allergic sensitization

Allergic sensitization was assessed by measuring specific IgE to common inhalant allergens in the subjects' serum using the Pharmacia SX₁-test (Pharmacia, Uppsala, Sweden). The SX₁-test is a screening assay to identify specific allergic sensitization against mite, cat, dog, *cladosporium herbarum* and pollen allergens (timothy grass, rye, birch, and mugwort). It is a qualitative test and the categorization of the assay results as positive or negative was based on the recommendations of the manufacturer.

Statistical analysis

We applied the likelihood-ratio- χ^2 -test to check whether the characteristics of the study population differed between the exposure categories. In order to assess the association between the health outcomes and passive smoking we used logistic regression analysis. Results were considered to be statistically significant at a 5% level. When performing subgroup testing we adjusted the alpha level using Bonferroni's correction. All analyzes were carried out using SAS V8 (SAS Institute, Cary, NC, USA).

Results

The characteristics of the study population with respect to gender, age, social status, number of siblings, residential region and community size are given in Table 1. A description of the exposure variable ETS and the health variables allergic sensitization and allergic rhinitis/conjunctivitis is presented in Table 2. We categorized ETS exposure into the following four groups: exposure only at work, only at home, both at work and at home, and neither at work nor at home. It should be noted that at the time when the survey was conducted there did not yet exist smoking guidelines for the workplace.

Table 1 Characteristics of the study population (non-smoking participants of the German National Health Survey 1998, *N* = 4093)

	<i>n/N</i>	%
Gender		
Female	2203/4093	54
Male	1890/4093	46
Age group (years)		
17–29	593/4093	15
30–39	769/4093	19
40–59	1653/4093	40
60–79	1078/4093	26
Social class		
Lower class	847/4057	21
Middle class	2239/4057	55
Upper class	971/4057	24
Number of siblings		
0	605/4072	15
1	1015/4072	25
2	946/4072	23
3	642/4072	16
≥4	864/4072	21
Residential region		
West Germany	2727/4093	67
East Germany	1366/4093	33
Community size		
<20 000	1354/4093	33
20 000–100 000	614/4093	15
100 000–500 000	715/4093	18
>500 000	1410/4093	34

Table 2 Description of exposure and health variables of the study population (non-smoking participants of the German National Health Survey 1998, *N* = 4093)

	<i>n/N</i>	%
Environmental tobacco smoke		
Only at work	687/4093	17
Only at home	341/4093	8
Both at work and at home	194/4093	5
Neither at work nor at home	2871/4093	70
Allergic sensitization ^a	1189/4093	29
Allergic rhinitis/conjunctivitis	661/3970	17

^aPositive SX₁-test.

Table 3 shows the characteristics of the study population within each of the four ETS exposure categories. When testing for differences in the distribution of each population characteristic over the four exposure categories, only the number of siblings and the community size were equally distributed among the ETS exposure groups. Therefore, gender, age, social class and residential region were considered as confounding factors in our regression models.

We calculated crude and adjusted odds ratios and their confidence limits in order to assess the association between ETS exposure and the health outcomes (Table 4). It could be seen that the effect of ETS exposure on allergic sensitization is biggest when it occurs at the workplace [confounder adjusted OR = 1.17 (0.97, 1.41)]; the same could be observed with respect to allergic rhinitis/conjunctivitis [confounder

Table 3 Description of the study population (non-smoking participants of the German National Health Survey 1998, $N = 4093$) by ETS exposure categories

	Environmental tobacco smoke				<i>P</i> -value ^a
	Both at work and at home ($N = 194$)	Only at work ($N = 687$)	Only at home ($N = 341$)	Neither at work nor at home	
Gender ($N = 4093$)					
Female	85 (4)	267 (12)	238 (11)	1613 (73)	<0.0001
Male	109 (6)	420 (22)	103 (6)	1258 (66)	
Age group ($N = 4093$)					
17–29	58 (10)	153 (26)	55 (9)	327 (55)	<0.0001
30–39	30 (4)	184 (24)	64 (8)	491 (64)	
40–59	97 (6)	321 (19)	134 (8)	1101 (67)	
60–79	9 (1)	29 (3)	88 (8)	952 (88)	
Social class ($N = 4057$)					
Lower class	51 (6)	95 (11)	93 (11)	608 (72)	<0.0001
Middle class	123 (6)	434 (19)	196 (9)	1486 (66)	
Upper class	19 (2)	154 (16)	48 (5)	750 (77)	
Number of siblings ($N = 4072$)					
0	29 (5)	92 (15)	64 (11)	420 (69)	0.337
1	53 (5)	194 (19)	81 (8)	687 (68)	
2	45 (5)	158 (16)	73 (8)	670 (71)	
3	26 (4)	108 (17)	45 (7)	463 (72)	
>4	41 (5)	132 (15)	75 (9)	616 (71)	
Residential region ($N = 4093$)					
West Germany	150 (5)	470 (17)	238 (9)	1869 (69)	0.001
East Germany	44 (3)	217 (16)	103 (8)	1002 (73)	
Community size ($N = 4093$)					
<20 000	66 (5)	218 (16)	110 (8)	960 (71)	0.771
20 000–100 000	28 (5)	96 (16)	46 (7)	444 (72)	
100 000–500 000	31 (4)	116 (16)	67 (10)	501 (70)	
>500 000	69 (5)	257 (18)	118 (8)	966 (69)	
Allergic sensitization ^b ($N = 4093$)					
Yes	61 (5)	254 (21)	92 (8)	782 (66)	<0.0001
No	133 (5)	433 (15)	249 (8)	2089 (72)	
Allergic rhinitis/conjunctivitis ($N = 3970$)					
Yes	30 (5)	140 (21)	55 (8)	436 (66)	0.011
No	158 (5)	523 (16)	275 (8)	2353 (71)	

Values are expressed as n (%).

^aTesting for an association between ETS categories and population characteristics using the likelihood-ratio- χ^2 -test.

^bPositive SX_1 -test.

Table 4 Association between ETS and health variables: odds ratios and confidence limits (non-smoking participants of the German National Health Survey 1998, $N = 4093$)

	Environmental tobacco smoke			
	Both at work and at home ($N = 194$)	Only at work ($N = 688$)	Only at home ($N = 341$)	Neither at work nor at home ($N = 2876$)
Allergic sensitization ^a				
OR	1.23 (0.90, 1.68)	1.57 ^b (1.32, 1.87)	0.99 (0.77, 1.27)	1
Adjusted ^c OR	0.96 (0.69, 1.33)	1.17 (0.97, 1.41)	0.99 (0.76, 1.29)	1
Allergic rhinitis/conjunctivitis				
OR	1.03 (0.68, 1.53)	1.45 ^b (1.17, 1.79)	1.08 (0.79, 1.47)	1
Adjusted ^c OR	0.89 (0.59, 1.35)	1.20 (0.96, 1.51)	1.05 (0.76, 1.43)	1

^aPositive SX_1 -test.

^bStatistically significant.

^cAdjusted for gender, age group, social class and residential region.

adjusted OR = 1.20 (0.96, 1.51)]. The observed odds ratios failed to be significant after confounder adjust-

ment, the strong drop in the OR being mostly attributable to age and gender. Nevertheless, there is still a tendency to an increased risk of allergic sensitization respectively allergic rhinitis/conjunctivitis when being exposed to ETS at work. ETS exposure at home did not show an effect on allergic sensitization or allergic rhinitis/conjunctivitis in our data (Table 4).

It is known that social status is usually correlated with ETS exposure, but in our analyzes the adjustment for social status had only a very small influence on the effect estimates: the OR for allergic sensitization when adjusting only for gender, age group and residential region, but leaving out social status, were 0.88 (0.63, 1.21), 1.14 (0.95, 1.38) and 0.94 (0.72, 1.22) for ETS exposure both at work and at home, only at work and only at home, respectively. Similar results were obtained for allergic rhinitis/conjunctivitis.

We also looked at the odds ratio for being exposed to ETS at some place (at home or at work or both) vs. not being exposed at any place. The effect for both allergic sensitization and allergic rhinitis/conjunctivitis was similar, showing an significantly increased risk only in the crude odds ratios and being only slightly elevated after confounder adjustment [confounder adjusted OR for allergic sensitization: 1.09 (0.93, 1.27), for allergic rhinitis/conjunctivitis: 1.11 (0.92, 1.34)].

We performed subgroup testing to find out if there was a gender difference in the effect of ETS exposure on allergic sensitization and allergic rhinitis/conjunctivitis. It could be seen that no single gender showed a consistently higher or lower tendency to experience allergic reactions when exposed to ETS (Table 5).

In a second subgroup analysis we investigated whether persons with an asthmatic history ($n = 278$, 6.8%) showed a different association between ETS exposure and allergic sensitization or allergic rhinitis/conjunctivitis. The results of this analysis were similar to those of the whole population (data not shown) thus indicating that asthmatics do not exhibit a different sensitization patterns when exposed to ETS.

Discussion

Our results show an increased but not statistically significant association between ETS exposure and allergic sensitization and allergic rhinitis/conjunctivitis in adults. No difference with respect to gender or asthmatic history could be observed in the relationship between ETS exposure and the two allergic outcomes.

There are some possible explanations for the lack of association between ETS exposure and allergy in this study. The genetic susceptibility to atopy is widely recognized but in our data information on atopic heredity is missing and could not be taken into account. Also, factors from the childhood environment, several of which are known to influence the development of allergic reactions in later life, could have influenced our

Table 5 Association^a between ETS and health variables for each gender: odds ratios and confidence limits (non-smoking participants of the German National Health Survey 1998, *N* = 4093)

	Allergic sensitization ^b		Allergic rhinitis/conjunctivitis	
	Female (<i>N</i> = 2203)	Male (<i>N</i> = 1890)	Female (<i>N</i> = 2150)	Male (<i>N</i> = 1820)
At work and at home				
OR	0.87 (0.48, 1.58)	1.44 (0.9 1, 2.29)	1.06 (0.54, 2.09)	1.01 (0.54, 1.91)
Adjusted ^c OR	0.71 (0.38, 1.31)	1.18 (0.73, 1.91)	0.91 (0.46, 1.81)	0.85 (0.44, 1.64)
Only at work				
OR	1.34 (0.97, 1.85)	1.60 ^d (1.23, 2.07)	1.70 ^d (1.19, 2.43)	1.31 (0.94, 1.84)
Adjusted ^c OR	1.01 (0.72, 1.41)	1.31 (0.99, 1.73)	1.39 (0.96, 2.01)	1.07 (0.74, 1.53)
Only at home				
OR	1.07 (0.75, 1.52)	0.95 (0.57, 1.57)	1.21 (0.80, 1.81)	0.74 (0.35, 1.54)
Adjusted ^c OR	1.04 (0.72, 1.50)	0.89 (0.52, 1.50)	1.18 (0.78, 1.78)	0.74 (0.35, 1.59)
Neither at work nor at home				
OR	1	1	1	1
Adjusted ^c OR	1	1	1	1
At work or at home or at both places				
OR	1.15 (0.90, 1.47)	1.45 ^d (1.15, 1.82)	1.40 ^d (1.06, 1.84)	1.16 (0.86, 1.57)
Adjusted ^c OR	0.97 (0.75, 1.26)	1.21 (0.94, 1.55)	1.23 (0.93, 1.64)	0.98 (0.71, 1.35)
Neither at work nor at home				
OR	1	1	1	1
Adjusted ^c OR	1	1	1	1

^aAdjusted for multiple testing.^bPositive SX₁-test.^cAdjusted for gender, age group, social status and residential region.^dStatistically significant.

results. Furthermore, our data on allergic rhinitis/conjunctivitis is questionnaire based and misclassifications can not be excluded. Additionally, the assessment of ETS exposure as done in this study is not very detailed since it does not specify the length and intensity subjects were exposed to cigarette smoke. Finally, as this is a cross sectional study, we do not have information on whether or not allergy occurred after ETS exposure.

Generally speaking it is much more difficult to detect a correlation between passive smoking and the development of allergic diseases in adults than it is in children, as adults are often exposed to an abundance of competitive factors which might explain the disease or mask the potential effect of passive smoking. Nevertheless, we observed a tendency of having a higher risk of sensitization when ETS exposure occurs at the workplace, and this fact might be even more meaningful when considering the uncertainties mentioned in the previous paragraph.

On the other hand, with respect to ETS exposure at home the odds ratios were close to one and this circumstance might indicate that other, occupational factors and not ETS could have been responsible for

sensitization at the workplace. But as the number of participants exposed to ETS only at home was quite low (8%), this might have lead to a poor statistical power for detecting a possible association between ETS and the health variables.

In summary, the findings from our study show a statistically non-significant tendency that exposure to ETS at the workplace increases allergic sensitization and allergic rhinitis in adults. This tendency could not be observed with respect to ETS exposure at home. Studies investigating the association of ETS and other diseases, effects of passive smoking were also mainly found at the workplace and not at home (Kreuzer et al., 2000, 2002; Radon et al., 2002). An explanation for this fact might be that exposure levels at the workplace are estimated to be higher than in the home environment (Repach and Lowrey, 1993) and time spent at the workplace might be longer (Leuenberger et al., 1995) thus leading to a more intensive ETS exposure at the workplace. It should also be taken into account that because of the difficulty of quantifying ETS exposure in our study, non-differential misclassification can not be excluded and might have lead to an underestimation of the health effects under consideration.

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