

Cigarette smoking is associated with high prevalence of chronic rhinitis and low prevalence of allergic rhinitis in men

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Abstract

Background: The harmful effects of tobacco smoke on human health, including respiratory health, are extensive and well documented. Previous data on the effect of smoking on rhinitis and allergic sensitization are inconsistent. We sought to investigate how smoking correlates with prevalence of allergic and chronic rhinitis among adults in Sweden.

Methods: The study population comprised 27 879 subjects derived from three large randomly selected cross-sectional population surveys conducted in Sweden between 2006 and 2008. The same postal questionnaire on respiratory health was used in the three surveys, containing questions about obstructive respiratory diseases, rhinitis, respiratory symptoms and possible determinants of disease, including smoking habits. A random sample from one of the cohorts underwent a clinical examination including skin prick testing.

Results: Smoking was associated with a high prevalence of chronic rhinitis in both men and women and a low prevalence of allergic rhinitis in men. These associations were dose dependent and remained when adjusted for a number of possible confounders in multiple logistic regression analysis. Prevalence of chronic rhinitis was lowest in nonsmokers and highest in very heavy smokers (18.5% vs 34.5%, $P < 0.001$). Prevalence of sensitization to common airborne allergens was lower in current smokers (25.9%, $P = 0.008$) and ex-smokers (28.2%, $P = 0.022$) than in nonsmokers (38.5%).

Conclusion: We found that smoking was associated with a high prevalence of chronic rhinitis in both sexes and a low prevalence of allergic rhinitis in men. The associations were dose dependent and remained when adjusting for several possible confounders.

The adverse effects of tobacco smoking on human health are extensive and well documented (1, 2). Tobacco smoking is considered the main preventable cause of death and disability worldwide (1), and the harmful properties of tobacco smoking affect several organ systems (2, 3). In the respiratory system, tobacco smoking is the chief cause for fatal diseases such as lung cancer and COPD (2), and exposure to

environmental tobacco smoke has been identified as a risk factor for asthma (4).

Tobacco smoke exerts a considerable, but complex, impact on the immune system (5). Smoking appears to increase the risk of a number of immunologic disorders (e.g. Crohn's disease and rheumatoid arthritis), but to reduce the risk of others (e.g. colitis and primary sclerosing cholangitis) (5).

Population studies on the association between tobacco smoking and allergic sensitization (6–12) and allergic rhinitis (12–21), respectively, have provided inconsistent results. There are reports of a lower prevalence of allergic rhinitis in smokers (12–18), as well as the opposite (20, 21). Previous studies on chronic rhinitis are few, but suggest an increased prevalence in smokers compared to nonsmokers (22–24).

It is well known that there are gender differences in the epidemiology and clinical presentation of allergic rhinitis and asthma (25, 26). However, the impact of smoking on rhinitis has rarely been studied for men and women separately (12), and never adjusting for possible confounders.

We sought to investigate the association between current and previous smoking and the prevalence of allergic and chronic rhinitis, respectively, in three large population-based cohorts in Sweden.

Methods

Study population

The study population was derived from three large population-based cross-sectional surveys conducted in Sweden between 2006 and 2008. Each cohort has previously been described in detail (23, 27). The 2006 and 2007 cohorts comprise subjects aged 30–79 and 20–69 years, respectively, from the city of Stockholm. The 2008 cohort comprises subjects aged 16–75 years from the region of West Gothia, including the city of Gothenburg. All data were attained by postal self-administered questionnaires. Names and addresses were provided by the Swedish Population Register. In total, 42 435 subjects were invited, of which 27 879 (65.7%) participated. The regional ethical committees of Stockholm and Gothenburg approved the studies.

Questionnaire

In all three surveys, the Obstructive Lung Disease in Northern Sweden (OLIN) study questionnaire was used. The OLIN questionnaire has been used in several large-scale studies in northern Europe (28–30) and contains questions about obstructive respiratory diseases, rhinitis, respiratory symptoms and possible determinants of disease, such as smoking, occupational exposures and family history of allergic diseases.

Skin prick test

In a clinical follow-up of the West Gothia cohort, a subset of 741 randomly selected subjects underwent skin prick testing to common airborne allergens including birch, timothy, mugwort, dog, cat, horse, *Dermatophagoides farinae*, *Dermatophagoides pteronyssinus*, *Cladosporium*, *Alternaria* (ALK, Hørsholm, Denmark) and *Blattella germanica* (Laboratorios LETI, Madrid, Spain). Histamine 10 mg/ml was used as a positive control, and glycerol as a negative control. Allergic sensitization was defined as mean wheal diameter of ≥ 3 mm after 15 min.

Definitions

Rhinitis

Allergic rhinitis: 'Do you have or have you ever had allergic rhinitis (hay fever) or allergic eye catarrh.'; *Nasal congestion*: 'Do you have nasal block more or less constantly'; *Runny nose*: 'Do you have a runny nose more or less constantly'; *Chronic rhinitis* was defined as having either nasal congestion or runny nose.

Smoking categories

Smokers were those currently smoking or having stopped smoking during the year preceding the survey (31). Smokers smoking less than 14 cigarettes per day were classed as *light-moderate smokers*, those smoking 14 through 24 cigarettes per day as *heavy smokers* and those smoking more than 24 cigarettes per day as *very heavy smokers*. *Ex-smokers* reported having stopped smoking at least 12 months preceding the survey. *Nonsmokers* reported neither smoking nor ex-smoking.

Other exposures

Family history of allergy: 'Have any of your parents or siblings ever had allergic eye or nose problems (hay fever)'; *Family history of asthma*: 'Has any of your parents or siblings ever had asthma'; *Airborne occupational exposure*: 'Have you been substantially exposed to dust, gases or fumes at work'; *Farm childhood*: 'Did your family live on a farm during your first five years of life'.

Analyses

Statistical analyses were performed using PASW version 17.0 (SPSS Inc., Chicago, IL, USA). Comparisons of proportions were tested with two-sided Fisher's exact test. The Mantel-Haenszel test was used for testing for trends. A *P*-value of <0.05 was regarded as statistically significant. Multiple logistic regression analysis was used to calculate odds ratios (ORs) with 95% confidence intervals (CIs) for allergic and chronic rhinitis, respectively. Independent variables were age, sex, family history of asthma, family history of allergy, smoking, occupational airborne exposure, farm childhood and study area. The interaction term 'ever smoking*sex' for allergic rhinitis was tested by multiple logistic regression analysis, adjusting for age and study area.

Results

Smoking habits

In total, 18.4% of the study population were smokers; 24.5% were ex-smokers; and 57.1% were nonsmokers (Table 1). Smoking habits varied considerably by age. The proportion of nonsmokers decreased rapidly with increasing age (70.7% in ages 16–30 years *vs* 47.4% in ages 61–80 years, $P < 0.001$). Correspondingly, the proportion of ex-smokers increased markedly by age. Light-moderate smoking was more common in young than in old subjects (16.6% in ages 16–30 years *vs*

Table 1 Smoking habits by sex and age. Difference (*P*-value) by sex

Age	Sex	Nonsmokers <i>n</i> (%)	Ex-smokers <i>n</i> (%)	Light-moderate smokers <i>n</i> (%)	Heavy smokers <i>n</i> (%)	Very heavy smokers <i>n</i> (%)
16–30 years	Men	1654 (75.7)***	162 (7.4)***	323 (14.8)***	38 (1.7) ^{ns}	8 (0.4) ^{ns}
	Women	2037 (68.1)***	326 (10.9)***	546 (18.3)***	74 (2.5) ^{ns}	8 (0.3) ^{ns}
31–45 years	Men	2503 (66.2)***	649 (17.2)***	464 (12.3) ^{ns}	130 (3.4) ^{ns}	33 (0.9)**
	Women	2873 (62.4)***	968 (21.0)***	562 (12.2) ^{ns}	186 (4.0) ^{ns}	16 (0.3)**
46–60 years	Men	1844 (49.4)**	1126 (30.2) ^{ns}	498 (13.3)***	216 (5.8) ^{ns}	48 (1.3)*
	Women	1951 (46.0)**	1364 (32.1) ^{ns}	686 (16.2)***	209 (4.9) ^{ns}	35 (0.8)*
61–80 years	Men	1235 (43.3)***	1145 (40.1)***	309 (10.8) ^{ns}	133 (4.7) ^{ns}	31 (1.1) ^{ns}
	Women	1699 (51.9)***	1032 (31.5)***	398 (12.2) ^{ns}	123 (3.8) ^{ns}	21 (0.6) ^{ns}
All ages	Men	7236 (57.7) ^{ns}	3082 (24.6) ^{ns}	1594 (12.7)***	517 (4.1) ^{ns}	120 (1.0) ^{ns}
	Women	8560 (56.6) ^{ns}	3690 (24.4) ^{ns}	2192 (14.5)***	592 (3.9) ^{ns}	80 (0.5) ^{ns}
All ages	Total	15 796 (57.1)	6772 (24.5)	3786 (13.7)	1109 (4.0)	200 (0.7)

Light-moderate smokers: ≤ 14 cigarettes per day; Heavy smokers: 14–24 cigarettes per day; Very heavy smokers: >24 cigarettes per day.

*** $P < 0.001$. ** $P < 0.01$. * $P < 0.05$. ^{ns}nonsignificant.

11.4% in ages 61–80 years, $P < 0.001$), whereas heavy (2.1% in ages 16–30 years vs 4.1% in ages 61–80 years, $P < 0.001$) and very heavy smoking (0.3% in ages 16–30 years vs 0.8% in ages 61–80 years, $P < 0.001$) were more common in older subjects. The prevalence of smoking and the differences between men and women were similar in the three studied cohorts.

Prevalence of allergic and chronic rhinitis

Prevalence of allergic rhinitis was 27.3%, and that of chronic rhinitis was 20.4% (Fig. 1). Close to half of those with chronic rhinitis reported also allergic rhinitis, and about a third of those with allergic rhinitis reported also chronic rhinitis.

There was a linear trend of a decreasing prevalence of allergic rhinitis with increasing smoking exposure among men ($P < 0.001$), while no consistent trend was found among women ($P = 0.055$) (Table 2). This trend among men was present and significant ($P < 0.05$) in all three cohorts (please see Table S1), as well as in both young (aged 16–45 years) and older men (aged 46–80 years) (Table 3).

Prevalence of chronic rhinitis increased with increasing smoking in a dose-dependent manner (Table 2). This trend

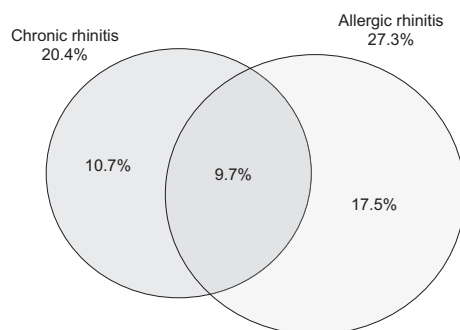


Figure 1 Venn diagram of prevalence of chronic rhinitis and allergic rhinitis.

was present and significant in all three cohorts (Table S1) and in all age and gender strata (Table 2).

Allergic rhinitis only was negatively associated with smoking; chronic rhinitis only was positively associated with smoking; and concomitant allergic and chronic rhinitis was weakly associated with smoking (please see Table S2).

Prevalence of allergic sensitization

Prevalence of sensitization to common airborne allergens was found to be considerably lower in current smokers (33.8%, P -value = 0.004) and ex-smokers (35.6%, P -value = 0.026) than in nonsmokers (46.0%) (Fig. 2). When analyses were made on groups of allergens, prevalence of allergic sensitization to pollens (i.e., birch, timothy and mugwort) was considerably lower in smokers (25.9%, P -value = 0.008) and ex-smokers (28.2%, P -value = 0.022) than in nonsmokers (38.5%) (Table 3). In contrast, prevalence of sensitization to house dust mites, moulds and furred animals was similar in the different smoking categories.

Smoking as a risk factor for rhinitis

The negative linear association between smoking exposure and allergic rhinitis, as well as the positive linear association between smoking exposure and chronic rhinitis, remained significant when adjusting for the effect of a number of confounders by multiple logistic regression analyses (Table 4). When stratifying the analyses by sex, the trend of decreasing ORs for allergic rhinitis with increasing smoking exposure was found in men, but not in women. The linear association between smoking exposure and chronic rhinitis was found in both sexes. Occupational airborne exposure yielded slightly higher odds ratios for allergic rhinitis in women than in men (OR 1.58 vs OR 1.12). For the remaining determinants, no obvious gender differences were found. The association of allergic rhinitis with smoking in men and women was different (P for interaction of sex*ever smoking <0.001), with men showing a strong negative association while no association was observed in women.

Table 2 Prevalence (%) of allergic and chronic rhinitis by smoking exposure, sex and age. Difference (*P*-value for trend) by smoking exposure

Age group	Smoking status	Allergic rhinitis			Chronic rhinitis		
		Men % (n)	Women % (n)	All % (n)	Men % (n)	Women % (n)	All % (n)
16–45 years	Nonsmokers	32.5 (1352)	31.3 (1536)	31.9 (2888)	20.1 (834)	19.8 (971)	19.9 (1805)
	Ex-smokers	32.8 (266)	34.2 (443)	33.7 (2105)	24.7 (200)	22.1 (286)	23.1 (486)
	Smokers						
	Light-moderate	29.2 (230)	30.2 (335)	29.8 (565)	27.6 (217)	25.8 (286)	26.5 (503)
	Heavy	23.2 (39)	27.7 (72)	25.9 (111)	27.4 (46)	30.8 (80)	29.4 (126)
	Very heavy	17.1 (7)	20.8 (5)	18.5 (12)	36.6 (15)	45.8 (11)	40.0 (26)
	<i>P</i> -value for trend	0.002	0.38	0.006	<0.001	<0.001	<0.001
46–80 years	Nonsmokers	22.2 (684)	24.6 (896)	23.5 (1580)	17.2 (529)	16.2 (592)	16.7 (1121)
	Ex-smokers	22.1 (501)	26.6 (637)	24.4 (1138)	20.5 (465)	19.7 (472)	20.1 (937)
	Smokers						
	Light-moderate	18.3 (148)	20.3 (220)	19.5 (368)	22.2 (179)	20.6 (223)	21.3 (402)
	Heavy	17.2 (60)	26.0 (86)	21.5 (146)	32.8 (114)	25.3 (84)	29.1 (198)
	Very heavy	7.6 (6)	35.7 (20)	19.3 (26)	26.6 (21)	39.3 (22)	31.9 (43)
	<i>P</i> -value for trend	<0.001	0.66	0.004	<0.001	<0.001	<0.001
All ages	Nonsmokers	28.1 (2036)	28.4 (2432)	28.3 (4468)	18.8 (1363)	18.3 (1563)	18.5 (2926)
	Ex-smokers	24.9 (767)	29.3 (1080)	27.3 (1847)	21.6 (665)	20.5 (758)	21.0 (1423)
	Smokers						
	Light-moderate	23.7 (378)	25.3 (555)	24.6 (933)	24.8 (396)	23.2 (509)	23.9 (905)
	Heavy	19.1 (99)	26.7 (158)	23.2 (257)	31.0 (160)	27.7 (164)	29.2 (324)
	Very heavy	10.8 (13)	31.2 (25)	19.0 (38)	30.0 (36)	41.2 (33)	34.5 (69)
	<i>P</i> -value for trend	<0.001	0.055	<0.001	<0.001	<0.001	<0.001

Light-moderate smokers: ≤ 14 cigarettes per day; Heavy smokers: 14–24 cigarettes per day; Very heavy smokers: >24 cigarettes per day.

Table 3 Prevalence (%) of allergic sensitization to common airborne allergens by smoking habits. Difference (*P*-value for trend) by smoking habits

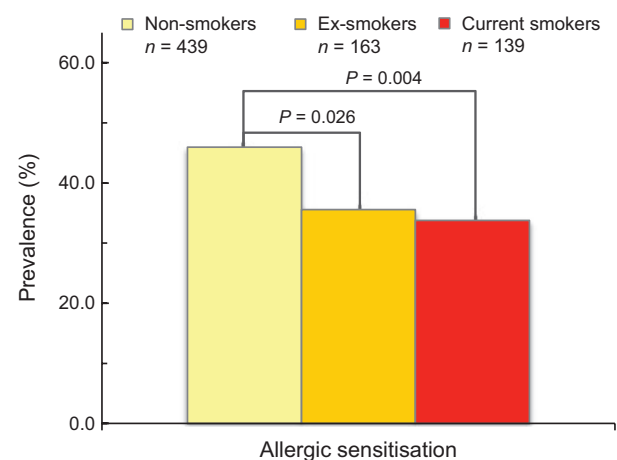
Smoking habits	Allergic sensitization				
	Pollens	House dust mites	Furred animals	Moulds	Any SPT
Nonsmokers	38.5	12.3	24.4	2.7	46.0
Ex-smokers	28.2	11.0	21.5	2.5	35.6
Smokers	25.9	12.2	18.0	0.7	33.8
<i>P</i> -value for trend	0.002	0.89	0.11	0.20	0.004

Pollens: Birch, timothy and mugwort; House dust mites: *Dermatophagoides farinae*, *Dermatophagoides pteronyssinus*; Furred animals: dog, cat, horse; Moulds: *Cladosporium*, *Alternaria*.

Discussion

We found that smoking was associated with a high prevalence of chronic rhinitis and a low prevalence of allergic rhinitis; both associations were dose dependent. The negative association between smoking and allergic rhinitis was marked in men, whereas in women, no significant trend was found. These findings were consistent when adjusting for a number of possible confounders by multiple regression analysis.

Previous studies have presented conflicting results on the effects of smoking on the prevalence of allergic rhinitis

**Figure 2** Prevalence (%) of allergic sensitization to common airborne allergens by smoking habits. *P*-values were calculated by Fisher's exact test, two-sided.

(12–18, 20, 21). A number of population-based studies on adults have found a lower prevalence of allergic rhinitis in smokers than in nonsmokers (12–17), and a Norwegian study reported a trend of a decreasing risk of allergic rhinitis with increasing number of cigarettes smoked per day (15). Furthermore, a longitudinal Japanese study found a decreased risk of cedar pollinosis in smokers compared to nonsmokers

Table 4 Risk factors for allergic and chronic rhinitis in men and women by multiple logistic regression analysis

Independent variables	Dependent variables					
	Allergic rhinitis			Chronic rhinitis		
	Men OR (95% CI)	Women OR (95% CI)	Total OR (95% CI)	Men OR (95% CI)	Women OR (95% CI)	Total OR (95% CI)
Smoking						
Nonsmoker	1	1	1	1	1	1
Ex-smoker	1.01 (0.91–1.13)	1.08 (0.99–1.19)	1.04 (0.97–1.12)	1.22 (1.09–1.36)	1.19 (1.07–1.31)	1.20 (1.12–1.29)
Light-moderate smoker	0.82 (0.72–0.95)	0.85 (0.76–0.95)	0.84 (0.77–0.91)	1.36 (1.20–1.56)	1.32 (1.17–1.48)	1.34 (1.29–1.46)
Heavy smoker	0.67 (0.52–0.85)	0.88 (0.72–1.07)	0.77 (0.66–0.90)	1.87 (1.52–2.28)	1.63 (1.34–1.98)	1.74 (1.51–2.00)
Very heavy smoker	0.33 (0.18–0.61)	1.07 (0.64–1.79)	0.61 (0.41–0.88)	1.77 (1.18–2.64)	2.89 (1.82–4.59)	2.17 (1.60–2.93)
Family history						
Neither	1	1	1	1	1	1
Asthma	1.67 (1.44–1.93)	1.81 (1.59–2.06)	1.76 (1.59–1.93)	1.33 (1.15–1.55)	1.46 (1.27–1.67)	1.40 (1.27–1.55)
Allergic rhinitis	5.89 (5.26–6.59)	4.92 (4.47–5.40)	5.32 (4.95–5.72)	1.60 (1.41–1.81)	1.76 (1.59–1.96)	1.69 (1.56–1.83)
Both	7.21 (6.21–8.36)	5.43 (4.85–6.07)	6.06 (5.54–6.62)	2.01 (1.72–2.34)	2.20 (1.95–2.48)	2.12 (1.93–2.33)
Airborne occupational exposure	1.12 (1.02–1.24)	1.58 (1.42–1.75)	1.29 (1.20–1.39)	1.67 (1.52–1.83)	1.93 (1.74–2.14)	1.78 (1.66–1.90)
Farm childhood	0.81 (0.70–0.94)	0.84 (0.74–0.95)	0.83 (0.75–0.91)	0.98 (0.86–1.13)	1.03 (0.90–1.17)	1.00 (0.91–1.10)
West Sweden (reference: Stockholm)	1.02 (0.93–1.11)	0.98 (0.90–1.06)	0.99 (0.93–1.05)	0.86 (0.79–0.95)	0.89 (0.82–0.97)	0.88 (0.82–0.93)
Age						
61–80 yrs.	1	1	1	1	1	1
46–60 yrs.	1.49 (1.31–1.70)	1.32 (1.18–1.47)	1.23 (1.13–1.34)	0.92 (0.80–1.04)	0.84 (0.75–0.95)	1.04 (0.95–1.13)
31–45 yrs.	1.16 (1.02–1.33)	1.21 (1.08–1.36)	1.45 (1.33–1.57)	0.85 (0.74–0.98)	0.82 (0.73–0.93)	1.09 (0.99–1.18)
16–30 yrs.	0.90 (0.77–1.05)	1.02 (0.90–1.17)	1.04 (0.95–1.15)	0.82 (0.70–0.95)	0.80 (0.70–0.91)	1.24 (1.12–1.37)

Boldface indicates statistical significance.

(19). In contrast, two studies on adolescent populations in Great Britain (21) and France (20) found a higher prevalence of allergic rhinitis in smokers than in nonsmokers. The British study found a trend of an increasing prevalence of rhinoconjunctivitis with increasing frequency of smoking (i.e., daily, weekly or less frequently). Interstudy differences may be due to differences in study populations and methods. In addition, geographical differences in sensitization patterns to airborne allergens may also contribute to the discrepancies. Because previous data suggest that smoking correlates differently with outdoor vs indoor allergens (9–11), the association between smoking and allergic rhinitis would possibly be different in areas where outdoor allergens predominate compared to areas where indoor allergens predominate.

Similarly to what has been reported for allergic rhinitis, population-based data on the impact of smoking on allergic sensitization are inconsistent (6–10). A prospective study from New Zealand found a considerably lower risk of developing allergic sensitization among smokers than among ex-smokers and nonsmokers with atopic parents (6). In line with these results, we found that the prevalence of allergic sensitization was lower in ex-smokers and current smokers than in nonsmokers. When analyses were performed on groups of allergens, we found an negative association between smoking and allergic sensitization for pollens, but

not for house dust mites, moulds or furred animals. These findings are in agreement with the results from the European Community Respiratory Health Survey (ECRHS) and the Swedish OLIN studies (9–11). The ECRHS found a negative association between smoking and sensitization to cat and grass pollen, but not to house dust mites (9), as well as a linear trend of a decreasing sensitization to cat and grass pollen, but not to house dust mites, with increasing number of pack years (10). The OLIN study, which was of longitudinal design, found a decreased risk of allergic sensitization to pollens, but not to animals, among smokers compared to nonsmokers, results in line with ours (11). In contrast to the inconsistent findings of population-based studies, several occupational surveys have identified smoking as a risk factor for developing sensitization to a number of different work-related allergens (32, 33). Our finding that smoking is negatively associated with sensitization to pollens, but not to other allergens, may either be due to different exposure to allergens in smokers than in nonsmokers or that smoking interacts differently with pollens than with other allergens on a mechanistic level. Smokers may spend less time outdoors and more time indoors than nonsmokers, thus being more exposed to house dust mites and less to pollens. However, we do not have data on time spent indoors vs outdoors in this study. Future studies are needed to verify such differences.

Few studies have investigated the influence of smoking on chronic nasal symptoms (22–24). A recent European large-scale multicentre study by Hastan et al. (22) found that chronic rhinosinusitis (CRS), defined according to the EP³OS criteria (34), was associated with smoking in many parts of Europe and in a dose-dependent manner. The outcome variable in this study was defined somewhat differently than in the current study. In the West Sweden cohort, 19.8% had chronic rhinitis, while 7.5% had CRS according to EP³OS. Close to one-third of those with chronic rhinitis also filled the criteria for CRS, and about 80% of those with CRS also had chronic rhinitis. Thus, the variable chronic rhinitis contains most subjects with CRS but also others with chronic nasal symptoms. Although definitions were not identical, our results are in line with those of Hastan et al.

Tobacco smoke has documented immunosuppressive properties, such as inhibition of the expression of pro-inflammatory cytokines (35), depletion of IgG levels and reduced T-cell activation (5). Because T-cell activation is required for the initiation of allergic sensitization, this may be a pathophysiological explanation to our findings. However, whether smoking or any specific compound of tobacco smoke may reduce allergic sensitization by impaired T-cell activation remains to be elucidated by future mechanistic studies.

Only two studies have investigated the association between smoking and allergic rhinitis in men and women separately (12, 19). Nagata et al. (19) found a decreased risk of onset of cedar pollinosis in both male and female smokers, compared to their nonsmoking counterparts. However, as the relationship between smoking and sensitization appears to be allergen specific, this finding cannot be applied to allergic rhinitis in general. Wüthrich et al. (12) found a considerably lower prevalence of allergic rhinitis in male smokers than in male nonsmokers. The same association was found also in women, but with smaller magnitude. However, the results from that study were not adjusted for possible confounders. Adjusting for a number of potential confounders, we found that the negative association between smoking exposure and allergic rhinitis was strong and dose dependent in men, while no association was found in women. The reason for this sex-specific difference can only be speculated upon. There are other documented examples of sex-specific differences in the immune response to smoking. For instance, smoking is a well-established risk factor for rheumatoid factor-positive rheumatoid arthritis in men, while epidemiological studies have provided inconsistent results for women (36). Moreover, some studies have found increased levels of total IgE in male, but not female, smokers (37). Apart from biological variances, a divergence in the symptom recognition and report between male and female smokers could contribute to the difference (38). Other possible explanatory factors for the gender difference could be age of starting smoking, the way the subjects smoke and the way they report their smoking. However, in this study, the age of starting smoking was similar between men and women.

Few studies have analysed risk factors for rhinitis for men and women separately. Apart from smoking, sex-specific differences in the associations between allergic rhinitis and

possible determinants were small. Exposure to gas, dust or fumes at work was a significant risk factor for allergic rhinitis (39) and yielded a slightly higher odds ratio in women than in men. A protective effect of being raised on a farm against allergic rhinitis, which has previously been reported (40), was found to be present and equally strong in women and men.

In the interpretation of the results from the current study, it is important to realize that the questions on allergic rhinitis and chronic nasal symptoms are not mutually exclusive (23). Rather, there is considerable overlap between the conditions. When analysing the group with both allergic rhinitis and chronic rhinitis separately, no clear association with smoking was found, thus confirming the divergent relationship between smoking and the two conditions, respectively.

This study benefits from its size, well-validated questions and fair response rate (66%). Further, the study population comprises the adult population in the two largest cities in Sweden, as well as a number of small and mid-sized towns and rural areas. The trends of an increasing prevalence of chronic rhinitis and a decreasing prevalence of allergic rhinitis with increasing smoking exposure were consistent in all three studied cohorts. The objective confirmation of a negative association between smoking and allergy by skin prick tests in a randomly selected subsample further strengthens our results. In cross-sectional studies, risk factor assessments must be interpreted with caution because associations may be due to reverse causation. In this study, we cannot completely rule out the possibility that men with allergic rhinitis self-selecting as nonsmokers might account for the apparent beneficial effect of smoking (healthy smoker bias). In order to assess causality, the associations between smoking and rhinitis found in the current study require confirmation by studies of longitudinal design. Another possible bias is the survivor bias, that is, the tendency of heavy smokers to die and thus be underrepresented in the analyses. However, it is most unlikely that such an effect would be modified by the presence of allergic rhinitis.

In conclusion, we found that smoking was associated with a high prevalence of chronic rhinitis in both sexes and with a low prevalence of allergic rhinitis in men. These associations were of a dose-dependent manner and remained significant when adjusting for a number of possible confounders.

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Authors' contributions

JE drafted the manuscript, performed the statistical analyses and participated in the collection of data. LE participated in

the collection of data and revised the manuscript. BMS revised the manuscript. JL, KT, ER, KL and BL participated in the design of the study and revised the manuscript. All authors read and approved the final manuscript.

Conflict of interest

The other authors declare no conflicting interests.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Cohort specific prevalence (%) of allergic and chronic rhinitis by smoking exposure and sex.

Table S2. Prevalence (%) of allergic rhinitis only, chronic rhinitis only and the combination of allergic and chronic rhinitis by smoking exposure.

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Table S1. Cohort specific prevalence (%) of allergic and chronic rhinitis by smoking exposure and sex. Difference (p-value for trend) by smoking exposure.

Cohort	Smoking exposure	Allergic rhinitis			Chronic rhinitis		
		Men	Women	All	Men	Women	All
Stockholm 2006	Non-smokers	28.1	31.1	29.7	18.5	20.5	19.6
	Ex-smokers	23.9	30.3	27.5	23.4	20.7	21.9
	Smokers						
	Light-moderate	26.7	21.9	23.9	26.7	23.3	24.8
	Heavy	18.2	26.3	22.6	39.4	29.7	34.1
	Very heavy	14.8	37.5	23.3	40.7	50.0	44.2
	<i>P-value for trend</i>	<i>0.017</i>	<i>0.014</i>	<i><0.001</i>	<i><0.001</i>	<i>0.005</i>	<i><0.001</i>
Stockholm 2007	Non-smokers	28.7	29.5	29.1	18.4	18.4	18.4
	Ex-smokers	25.8	29.9	28.0	22.3	21.1	21.6
	Smokers						
	Light-moderate	27.5	25.4	26.4	32.2	23.8	27.6
	Heavy	19.7	26.7	23.2	25.9	33.3	29.6
	Very heavy	6.7	22.7	13.5	30.0	36.4	32.7
	<i>P-value for trend</i>	<i>0.01</i>	<i>0.13</i>	<i>0</i>	<i><0.001</i>	<i><0.001</i>	<i><0.001</i>
West Sweden 2008	Non-smokers	28.0	27.5	27.7	19.0	17.7	18.3
	Ex-smokers	24.9	28.7	27.0	20.8	20.3	20.5
	Smokers						
	Light-moderate	21.7	26.1	24.3	21.9	23.0	22.6
	Heavy	19.3	26.9	23.4	30.2	25.2	27.5
	Very heavy	11.1	33.3	20.0	25.4	40.5	31.4
	<i>P-value for trend</i>	<i><0.001</i>	<i>0.70</i>	<i><0.001</i>	<i><0.001</i>	<i><0.001</i>	<i><0.001</i>

Light-moderate smokers: ≤14 cigarettes per day; Heavy smokers: 14-24 cigarettes per day; Very heavy smokers: >24 cigarettes per day.

Table S2. Prevalence (%) of allergic rhinitis only, chronic rhinitis only and the combination of allergic and chronic rhinitis by smoking exposure. Difference (p-value for trend) by smoking exposure.

Smoking status	Allergic rhinitis only	Chronic rhinitis only	Allergic and chronic rhinitis
Non-smokers	19.0	9.2	9.3
Ex-smokers	17.0	10.8	10.2
Smokers			
Light-moderate	14.8	14.0	9.9
Heavy	11.5	17.4	11.7
Very heavy	8.0	23.5	11.0
<i>P-value for trend</i>	<i><0.001</i>	<i><0.001</i>	<i>0.005</i>

Light-moderate smokers: ≤14 cigarettes per day; Heavy smokers: 14-24 cigarettes per day; Very heavy smokers: >24 cigarettes per day.