

Both environmental tobacco smoke and personal smoking is related to asthma and wheeze in teenagers

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ABSTRACT

Background Environmental tobacco smoke (ETS) has been reported as a significant risk factor for childhood asthma. Among adults, personal smoking is a major cause of respiratory symptoms and diseases. The effects of these exposures on the prevalence of asthma and wheeze among teenagers are less well known.

Objective The aim was to study the independent and combined effects of ETS and personal smoking on the prevalence of asthma and wheeze in teenagers.

Methods A longitudinal study of asthma and allergic diseases in schoolchildren has been in progress in Northern Sweden since 1996. All children aged 7–8 years in three municipalities were invited and 3430 (97%) participants have been followed by annual questionnaires. At the age 16–17 years, 82% of the initial participants took part in the 2005 survey.

Results Prevalence of physician-diagnosed asthma, ever wheeze and current wheeze was significantly higher among those exposed to maternal ETS and among daily smokers. In multivariate analyses, maternal ETS was a significant risk factor for physician-diagnosed asthma and ever wheeze (OR 1.3–1.5) and personal daily smoking for current wheeze (OR 2.0). ORs for asthma and ever wheeze were highest among daily smokers who were also exposed to maternal ETS with ORs of 1.7 and 2.5, respectively. A significant dose–response association between number of cigarettes/day and the prevalence of wheeze was also found.

Conclusions Both ETS and personal smoking were significantly related to asthma and wheeze in teenagers. Maternal ETS exposure was associated with lifetime symptoms, but daily smoking among the teenagers was more strongly related to current symptoms.

INTRODUCTION

Exposure to environmental tobacco smoke (ETS) in early life, especially that from the mother, and maternal smoking during pregnancy are known risk factors for respiratory symptoms and asthma among children.^{1–4} However, less is known of the association between ETS and respiratory symptoms and asthma in teenagers. Some studies found an increased risk for asthma and respiratory symptoms among young adults exposed to ETS in childhood^{5 6} or in utero⁷ while others have not found such associations.⁸

Smoking is a major cause of respiratory symptoms, chronic bronchitis and chronic obstructive pulmonary disease (COPD) among adults.^{9 10} The association between smoking and asthma among

adults is not as strong or consistent.¹¹ While cross-sectional studies have primarily found relationships between asthma and ex-smoking or ever smoking,¹² several longitudinal studies have found significant associations between current smoking and the onset of asthma.^{1 13 14} Among teenagers, smoking is reported to be a risk factor for asthma and wheeze in both cross-sectional¹⁵ and longitudinal studies.^{1 7 8 16–19} Few studies have reported on the independent and combined effects of ETS and personal smoking on respiratory health among teenagers. In a French cross-sectional study, a higher risk of wheeze and asthma was found among smokers exposed to ETS compared to the non-exposed.¹⁵ Furthermore, in utero ETS exposure increases the risk of incident asthma among smoking teenagers.⁷

Within the Obstructive Lung Disease in Northern Sweden (OLIN) studies, a prospective cohort study about asthma and allergies among school children has been in progress since 1996. This study previously demonstrated associations between maternal smoking and prevalence of asthma at age 7–8 years⁴ and increased incidence of asthma during the following 2 years.²⁰ Parental smoking also increased the risk of smoking initiation during adolescence.²¹ The present study aimed to explore the independent and combined effects of ETS and personal smoking on the prevalence of asthma and wheeze among teenagers.

MATERIAL AND METHODS

Study population

The OLIN paediatric study I is a longitudinal study about asthma, rhinitis, eczema and allergic sensitisation among school children in Northern Sweden that started in 1996. Its aims and methods have been described previously.⁴ The parents of all 3525 children aged 7 and 8 years who enrolled in the first and second grades in three municipalities in Northern Sweden were invited to complete a questionnaire. Ninety-seven per cent (n=3430) participated, thus forming a cohort that has been followed by annual questionnaires. The study population in this paper consisted of 2805 children (50.5% boys) who participated in 1996 and again in 2005 at the age of 16–17 years (82% of the original 1996 participants). The study was approved by the Ethics Committee at Umeå University, Sweden.

Questionnaire

The questionnaire included the International Study of Asthma and Allergies in Childhood (ISAAC) core

questionnaire²² with additional questions about symptoms, physician diagnosis of asthma and allergic diseases, parental smoking habits and other possible risk factors.²³ Between ages 7–8 and 11–12 years, the questionnaire was completed by the parents. From 12 to 13 years of age and onwards, the teenagers completed the questionnaire at school and questions regarding personal tobacco use were added.^{21 24}

Definitions

Definitions that were based on the 2005 questionnaire:

Ever wheeze: 'Have You ever had wheezing or whistling in the chest at any time in the past?'

Current wheeze: 'Yes' to any of the following: 'Have You had wheezing or whistling in the chest in the last 12 months?', 'In the last 12 months, has Your chest sounded wheezy during or after exercise?', 'In the last 12 months, have You had wheezing or whistling in the chest without having a cold?' or those reporting more than one attack in the question 'How many attacks of wheezing have You had in the last 12 months?'

Physician-diagnosed asthma: 'Have You been diagnosed by a physician as having asthma?'

Current asthma: Physician-diagnosed asthma, and either wheeze or use of asthma medication during the last 12 months.

Personal smoking habits were assessed by one question that was completed by all participants: 'Do you smoke?', and two follow-up questions directed to smokers: 'How often do you smoke?' and 'How much do you smoke?'

1. *Occasional smokers*: Smoking on weekends or at parties.

2. *Daily smokers*: Smoking 'Daily' or 'Almost daily'.

Definitions that were based on data from 1996 to 2005:

In utero exposure: Mother smoked during pregnancy

ETS at age 7–8 (16–17) years: Mother (father) smoked in 1996 (2005).

Continuous ETS: Mother (father) smoked at all surveys from 1996 to 2005.

Family history of asthma: Mother, father or sibling had asthma as reported in 1996.

Current place of residence: Living in a house, an apartment or both, as reported in 2004.

House dampness: A report of past or present dampness at home in any of the questionnaires from 1996 to 2005.

Data management and statistical analysis

For the lifetime outcomes (ever wheeze and physician-diagnosed asthma) and the current status (current wheeze and current asthma at 16–17 years) missing answers to individual questions (<1%) were coded as negative responses. Missing answers to questions about ETS exposure (4–7%) and personal smoking (<1%) were assigned the response given in the previous questionnaire.

Analyses were made using the computer software programme Statistical Package for Social Sciences (SPSS Version 16.0; SPSS Inc, Chicago, Illinois, USA). For assessment of differences in prevalence, χ^2 -tests were used and a p value <0.05 was considered statistically significant. The effect of ETS and smoking on asthma and wheeze was analysed by multiple logistic regression analyses and expressed as ORs with 95% CIs. All multivariate analyses included the covariates sex, family history of asthma, current place of residence, house dampness and low birth weight (<2500 g) because each is a known risk factor for asthma or related to personal smoking in this cohort.^{4 20 21}

Because maternal ETS and personal smoking are correlated,²¹ their effect was analysed in different multivariate models. In all models, the ETS variables were tested one at a time in separate

analyses. Model A included maternal ETS and personal daily smoking, while Model B included maternal ETS and number of cigarettes smoked per day among the teenagers. Models C and D are presented in table S1 in the online supplement. In model C, only ETS variables were included and tested one at a time in separate analyses. Model D included four mutually exclusive exposure categories based on maternal ETS exposure and personal daily smoking. In a fifth model, the effect of maternal ETS exposure on asthma and wheeze was analysed among the non-smokers.

RESULTS

At age 7–8 years, the study population and those lost to follow-up reported almost identical prevalence of asthma and wheeze. However, the prevalence of ETS exposure at age 7–8 years was higher among those lost to follow-up compared to the study population; 40.0% vs 28.9% ($p<0.001$) were exposed from their mothers and 27.2% vs 21.4% ($p<0.01$) from their fathers.

Prevalence of asthma and wheeze

Among the 7–8-year olds, all asthma and wheeze variables were significantly more common among boys. At 16–17 years of age, both *ever wheeze* and *current wheeze* were more common among girls, while *physician-diagnosed asthma* and *current asthma* did not differ significantly by sex. The prevalence of all asthma and wheeze variables increased significantly by age (table 1). Among those with *current wheeze* at age 16–17 years, 41% reported *physician-diagnosed asthma*. Of those with *physician-diagnosed asthma* and *current asthma* at age 16–17 years, 39% and 38%, respectively, reported physician-diagnosed asthma also in the 1996 survey at age 7–8 years.

Prevalence of ETS exposure and smoking

The prevalence of current maternal and paternal ETS exposure decreased significantly during the study period (table 1). Of the mothers who were current smokers in 2005, 60% smoked during pregnancy and continuously during the study period. The prevalence of continuous ETS exposure was 14% for maternal, 7% for paternal and 3% were continuously exposed by both parents. Significantly more girls than boys had continuous exposure and current exposure to maternal ETS at age 16–17 years.

Daily smoking was significantly more common among girls, while occasional smoking was equally common among girls and boys (table 1). Of the daily smokers, 75% smoked 1–10 cigarettes per day, and 55% of them currently had ETS exposure from at least one parent. Among the occasional smokers, 42% reported current ETS exposure from at least one parent. These results were similar in boys and girls. The prevalence of daily smoking was 31% among those continuously exposed to maternal ETS compared to 7% ($p<0.001$) among those not continuously exposed. Smoking habits were similar among those with and without a family history of asthma.

Asthma and wheeze in relation to ETS

Statistically significant associations were found between all maternal ETS variables and *physician-diagnosed asthma*, *ever wheeze* and *current wheeze* with one exception: in utero exposure was not related to *ever wheeze*. Paternal ETS was not related to asthma or wheeze among the teenagers, except for ETS exposure at age 7–8 years, which was significantly associated with *current wheeze* at age 16–17 years (table 2).

Table 1 Prevalence (%) of asthma, wheeze, environmental tobacco smoke (ETS) exposure at age 7–8 and 16–17 years, and personal smoking habits at age 16–17 years

	Age 7–8 years			Age 16–17 years			Difference by age p value
	Boys (n=1416)	Girls (n=1389)	Difference by gender p value	Boys (n=1416)	Girls (n=1389)	Difference by gender p value	
<i>Outcome variables</i>							
Physician-diagnosed asthma	7.5	4.2	0.001	13.6	13.0	0.680	<0.001
Current asthma	6.9	4.0	0.001	8.9	10.9	0.080	0.012
Ever wheeze	24.8	17.5	0.001	21.9	26.1	0.010	<0.001
Current wheeze	11.4	8.3	0.007	16.5	24.8	0.001	<0.001
<i>Exposure to tobacco smoke</i>							
In utero exposure	23.1	24.3	0.439	—	—		
Current maternal ETS	27.5	30.2	0.264	21.6	25.4	0.018	<0.001
Current paternal ETS	20.1	22.7	0.110	18.4	19.1	0.619	0.016
Continuous ETS mother	—	—		12.8	15.6	0.031	
Continuous ETS father	—	—		6.4	7.0	0.505	
<i>Smoking habits</i>							
Occasional smokers	—	—		8.8	9.6	0.493	
Daily smokers	—	—		5.7	11.4	<0.001	

Asthma and wheeze in relation to smoking

The prevalence of *physician-diagnosed asthma*, *ever wheeze* and *current wheeze* was significantly higher among daily smokers compared to non-smokers (table 2). The prevalence of *current asthma* was slightly higher among daily smokers compared to non-smokers and the association was of borderline significance. Further, a significant dose–response association was found between the number of cigarettes smoked per day and the prevalence of *physician-diagnosed asthma*, *ever wheeze* and *current wheeze* (figure 1). The combination of current maternal ETS exposure and daily smoking yielded the highest prevalence estimates of all the asthma and wheeze variables (figure 2). The prevalence of asthma and wheeze did not differ significantly between non-smokers and occasional smokers (data not shown).

Multivariate relationships

In multivariate analyses, the associations between the different ETS variables and *physician-diagnosed asthma* remained significant or borderline significant with ORs of 1.3–1.5 (table S1;

Model C). Corresponding analyses for *ever wheeze* and *current wheeze* showed similar results. After adjusting to personal daily smoking among the teenagers (table 3; Model A) similar ORs for the ETS variables were obtained, but some of the associations became borderline significant. Daily smoking was significantly associated with *ever wheeze* and *current wheeze* (OR 1.9–2.0). A dose–response association between number of cigarettes smoked per day and the risk for *ever wheeze* and *current wheeze* was found (table 3; Model B). The highest ORs were obtained for the combination of being a daily smoker and currently ETS exposed with ORs of 2.6 (95% CI 1.7 to 3.9) for *ever wheeze*, 2.3 (95% CI 1.5 to 3.6) for *current wheeze*, and 1.7 (95% CI 1.0 to 2.9) for *physician-diagnosed asthma* (table S1; Model D). No interaction between maternal ETS and personal daily smoking was found.

The effect of ETS was analysed separately among the non-smokers. The multivariate analyses were similar to those for the whole study population and showed a positive association between ETS and *physician-diagnosed asthma* and *ever wheeze* (table 4).

Table 2 Prevalence (%) of asthma and wheeze at age 16–17 years in relation to environmental tobacco smoke (ETS) and personal daily smoking

		Physician-diagnosed asthma	Difference p value	Ever wheeze	Difference p value	Current wheeze	Difference p value
<i>Exposure to tobacco smoke</i>							
In utero exposure	No	12.5	0.041	23.3	0.199	19.7	0.032
	Yes	15.6		25.7		23.6	
Maternal ETS at age 7–8 years	No	12.0	0.008	22.0	0.002	19.2	0.005
	Yes	15.8		27.5		24.0	
Maternal ETS at age 16–17 years	No	12.4	0.023	22.6	0.005	19.5	0.009
	Yes	16.0		27.9		24.2	
Continuous maternal ETS	No	12.5	0.002	22.9	0.002	19.9	0.016
	Yes	18.1		30.2		25.1	
Paternal ETS at age 7–8 years	No	12.4	0.352	22.9	0.398	19.3	0.018
	Yes	13.9		24.6		23.9	
Paternal ETS at age 16–17 years	No	12.9	0.636	23.3	0.293	19.9	0.150
	Yes	13.7		25.5		22.8	
Continuous paternal ETS	No	13.3	0.847	23.9	0.972	20.2	0.050
	Yes	12.8		24.1		26.2	
<i>Smoking habits</i>							
Daily smoking	No	12.9	0.025	22.8	<0.001	19.3	<0.001
	Yes	18.0		36.8		34.7	

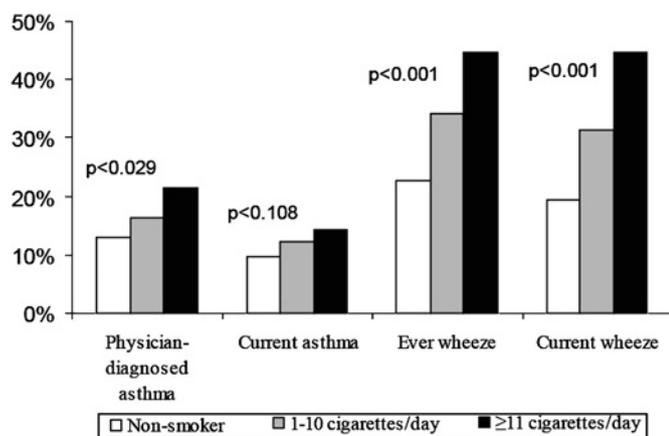


Figure 1 Prevalence (%) of asthma and wheeze at age 16–17 years in relation to the number of cigarettes smoked per day by χ^2 -test for trend.

DISCUSSION

In this study, we found that both exposure to maternal ETS and personal smoking were independently related to asthma and wheeze among teenagers. Maternal ETS exposure was a significant risk factor for physician-diagnosed asthma, but the association between personal smoking and current wheeze was stronger. The prevalence of asthma and wheeze was highest among daily smokers who were exposed to maternal ETS.

The strong association between daily smoking and current respiratory symptoms is consistent with literature showing that smoking during adolescence is related to respiratory symptoms.^{1 7 8 15–19} However, only few studies have reported on both the independent and the combined effects of ETS and personal smoking on respiratory health among teenagers.^{15 19} Both maternal ETS exposure and personal smoking were independently related to asthma and wheeze, and the combination of the two exposures yielded the highest risk of asthma and wheeze. Further, by age 16–17 years, we found a dose–response association with the highest prevalence of wheeze among those who smoked ≥ 11 cigarettes per day. These results indicate that adverse effects of smoking occur within a few years of smoking initiation.

An important aspect to consider in studies of the effect of ETS exposure among teenagers is that the teenagers might be smokers. Teenagers with family members who smoke are at higher risk of being smokers themselves.^{21 25} Previous analyses of

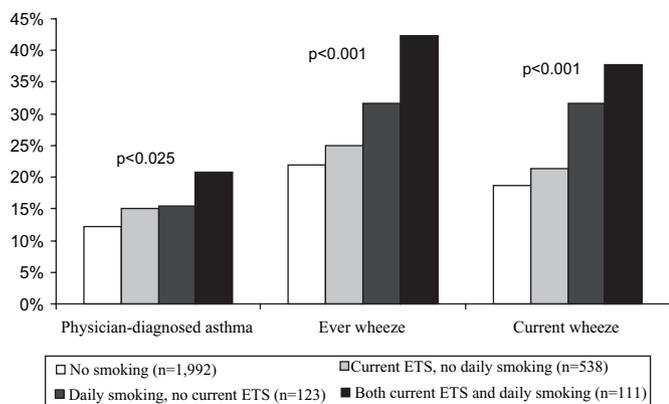


Figure 2 Prevalence (%) of asthma and wheeze at age 16–17 years in relation to personal daily smoking and current maternal environmental tobacco smoke (ETS) exposure.

the present cohort found a stepwise increase in prevalence of smokers with an increase in the number of smoking family members.²¹ In the present study, 55% of the daily smokers had a smoking parent, and thus it may be difficult to separate the effects of ETS and personal smoking. Although there were no statistically significant interactions, the ORs for both asthma and wheeze were highest among daily smokers exposed to ETS. This confirms the results from a limited number of previous studies that analysed the independent and combined effects of ETS exposure and personal smoking on asthma and wheeze.^{15 19} In contrast to a previous incidence study,⁸ we found independent effects of past and present ETS exposure on the prevalence of asthma also among non-smoking teenagers.

Our results support findings that maternal ETS exposure has a greater effect than paternal ETS exposure on the prevalence of asthma and wheeze.^{1 19} Previous studies of this cohort found that maternal smoking was associated with the prevalence of asthma at age 7–8 years⁴ as well as incident asthma during subsequent years.²⁰ In the present study, maternal ETS exposure remained a significant risk factor for the lifetime symptoms at 16–17 years, that is, physician-diagnosed asthma and ever wheeze, but not for current symptoms. One explanation for these results may be that the ETS exposure decreases as the children spend less time with their parents during adolescence compared to earlier. Another likely explanation may be that early ETS exposure is more important than late exposure and has an effect on respiratory health lasting into adolescence. Smoking during pregnancy is strongly related to fetal growth impairment, reduced lung function at birth and subsequent development of asthma.^{26 27} In line with our findings, Gilliland *et al* found in utero ETS exposure to be associated with physician-diagnosed asthma in childhood³ and in adolescence,⁷ while postnatal ETS exposure was only associated with wheeze in childhood.³ However, in a British cohort study that followed participants from birth to age 33 years, the combination of ETS exposure in utero and at 16 years of age was associated with the development of asthma after 17 years of age.¹ These inconsistencies may be explained by the use of different exposure and outcome time frames, or by the complex associations between pre- and postnatal ETS exposure and subsequent personal smoking.

At 7–8 years of age, ETS exposure was equally common among boys and girls. However, at age 16–17 years more girls were exposed to maternal ETS and more girls were daily smokers (table 1). Role modelling is important during adolescence. Having a smoking mother increases the risk of becoming a smoker.²¹ Thus, the explanation for the higher prevalence of maternal smoking among girls compared to boys might be that role modelling works in both directions—having a smoking daughter increase the likelihood that the mother continues to smoke.

Calculations of the incidence of asthma and wheeze in relation to tobacco smoke would have further strengthened our results. Despite that the annual incidence of asthma in teenagers is estimated at approximately 1/100 per year,^{16 17} the number of new cases with asthma and wheeze in our cohort was small, and further, the teenagers had smoked for a short period of time. Therefore, we were unable to study daily smoking as a risk factor for the incidence of asthma in this report. However, this will be an important issue in future follow-up studies of this population.

The strengths of this study include the longitudinal design, high participation rates and use of validated survey questions. The internationally used and validated ISAAC protocol was the source of questions about wheeze and asthma. The study design enabled reliable data of ETS exposure with less risk of recall bias.

Table 3 Environmental tobacco smoke (ETS) exposure from the mother at different time points* and personal smoking as risk factors for asthma and wheeze at age 16–17 years

		Physician-diagnosed asthma		Ever wheeze		Current wheeze	
		OR	95% CI	OR	95% CI	OR	95% CI
Model A	In utero exposure	1.22	0.94 to 1.59	1.05	0.85 to 1.30	1.16	0.93 to 1.45
	Daily smoking	1.33	0.91 to 1.94	1.87	1.39 to 2.52	1.97	1.46 to 2.67
	ETS at age 7–8 years	1.30	1.02 to 1.67	1.26	1.03 to 1.54	1.19	0.97 to 1.47
	Daily smoking	1.32	0.90 to 1.93	1.88	1.40 to 2.53	1.96	1.45 to 2.66
	ETS at age 16–17 years	1.25	0.96 to 1.63	1.21	0.98 to 1.50	1.15	0.92 to 1.45
	Daily smoking	1.36	0.93 to 1.98	1.89	1.41 to 2.55	1.99	1.47 to 2.70
Model B	Continuous ETS	1.47	1.09 to 1.99	1.34	1.04 to 1.71	1.18	0.91 to 1.54
	Daily smoking	1.35	0.93 to 1.96	1.87	1.39 to 2.50	1.99	1.47 to 2.68
	In utero exposure	1.22	0.82 to 1.82	1.05	0.85 to 1.30	1.16	0.93 to 1.45
	1–10 cigarettes/day	1.22	0.82 to 1.82	1.75	1.29 to 2.38	1.76	1.29 to 2.42
	≥11 cigarettes/day	1.38	0.69 to 2.72	1.94	1.12 to 3.37	2.44	1.41 to 4.22
	ETS at age 7–8 years	1.31	1.02 to 1.68	1.26	1.03 to 1.54	1.19	0.97 to 1.47
	1–10 cigarettes/day	1.18	0.78 to 1.77	1.68	1.23 to 2.29	1.74	1.26 to 2.39
	≥11 cigarettes/day	1.32	0.67 to 2.62	1.98	1.15 to 3.41	2.34	1.35 to 4.05
	ETS at age 16–17 years	1.26	0.96 to 1.64	1.21	0.98 to 1.51	1.15	0.92 to 1.44
	1–10 cigarettes/day	1.22	0.81 to 1.82	1.70	1.24 to 2.31	1.77	1.29 to 2.44
	≥11 cigarettes/day	1.33	0.67 to 2.63	1.96	1.14 to 3.86	2.35	1.35 to 4.07
	Continuous ETS	1.48	1.10 to 2.00	1.34	1.04 to 1.72	1.19	0.91 to 1.55
1–10 cigarettes/day	1.96	0.80 to 1.78	1.72	1.27 to 2.34	1.74	1.27 to 2.38	
≥11 cigarettes/day	1.47	0.76 to 2.82	2.03	1.19 to 3.46	2.42	1.42 to 4.15	

ORs were calculated by multiple logistic regression analyses, adjusting for sex, family history of asthma, current place of residence, house dampness and birth weight <2500 g.

*The variables regarding ETS from the mother were included one at a time.

Limitations of the study are that we lack information about how much the mothers smoked during pregnancy and that detailed validation of the self-reported smoking habits has not been done. However, others have validated self-reported smoking by measuring cotinine levels and found good agreement.²⁸ The reliability of the smoking reports in the present study is supported by the prevalence of smoking being similar to the Swedish average.²⁴ Further, a comparative study between questionnaires completed by the parents and the teenagers in this cohort show very good agreement for the questions about parental smoking.²⁹ In the present study, self-reported physi-

cian-diagnosed asthma was not validated against objective methods. However, previous studies of the cohort have shown a very high specificity⁴ and a high agreement between parents and teenagers in the question about diagnosis of asthma.³⁰

In conclusion, both ETS and personal smoking were significantly related to asthma and wheeze in teenagers. While exposure to maternal ETS was associated with lifetime symptoms, personal daily smoking was more strongly related to current symptoms. Effective smoking prevention programs among teenagers, particularly young women, are necessary to reduce the number of smokers and to improve public health.

Table 4 Environmental tobacco smoke (ETS) exposure from the mother as risk factor for asthma, ever wheeze and current wheeze in non-smokers at age 16–17 years expressed as adjusted ORs by multiple logistic regression analyses*

Independent variables	Categories	Dependent variables					
		Physician-diagnosed asthma		Ever wheeze		Current wheeze	
		OR	95% CI	OR	95% CI	OR	95% CI
In utero exposure	No	1		1		1	
	Yes	1.26	0.94 to 1.70	1.07	0.84 to 1.37	1.19	0.93 to 1.54
ETS at age 7/8	No	1		1		1	
	Yes	1.42	1.07 to 1.87	1.27	1.02 to 1.59	1.21	0.95 to 1.54
ETS at age 16/17	No	1		1		1	
	Yes	1.40	1.04 to 1.88	1.26	0.98 to 1.61	1.20	0.92 to 1.56
Continuous ETS exposure	No	1		1		1	
	Yes	1.51	1.07 to 2.14	1.43	1.07 to 1.92	1.23	0.90 to 1.67

*Other variables included in the models were sex, family history of asthma, current place of residence, house dampness and birth weight <2500 g. The variables regarding ETS from the mother were included one at a time.

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Competing interests None.

Ethics approval This study was conducted with the approval of the The Ethics Committee at Umeå University, Sweden.

Provenance and peer review Not commissioned; externally peer reviewed.

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