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Self-reported traffic density and atopic disease in children. Results of the ISAAC Phase III survey in Muenster, Germany

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Positive associations between traffic exposure and atopic respiratory disorders in children have been described in several studies. We analyzed data related to self-reported truck traffic density and several symptoms and diagnoses of asthma and hay fever (12-month wheezing and rhinitis symptoms, diagnoses of asthma and hay fever) from the ISAAC Phase III survey in Muenster, Germany, using core written and video questionnaires. Data were collected from representative school-based samples (n = 7345) of 6–7- and 13–14-yr-olds. In 13–14-yr-olds, according to exposure levels categorized into rare, frequent, and constant, with the 'never'-category used as reference, the sex-adjusted prevalence ratios were 1.29 (95% CI = 1.08–1.53), 1.58 (1.29–1.94), and 1.57 (1.18–2.10) for wheeze in the past 12 months, and 1.20 (1.06–1.34), 1.35 (1.17–1.55), and 1.69 (1.42–2.0) for rhinitis symptoms in the past 12 months. Prevalence ratios in 6–7-yr-olds and results for a diagnosis of asthma were less consistent while no positive association was detected between hay fever and truck traffic in both age groups. When analyses were based on a more general traffic indicator (self-reported traffic noise), no consistent associations were observed. Our data provide support for the hypothesis that residential exposure to truck traffic may adversely affect the health of children.

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In several countries, an increasing trend in symptoms of asthma and atopic disorders has been observed in children over the last decades (1, 2). This phenomenon is generally 'explained' by factors that are associated with a 'western' lifestyle (1). Several hypotheses focused on the possible association of allergic diseases with airborne pollution, e.g., NO_2, SO_2, ozone, black smoke, and fine and ultrafine particles, inside and outside of homes. Air pollutants associated with heavy traffic (NO_2) or industrial pollution (SO_2) have been shown to enhance airway response (3). Particles from diesel exhaust have been reported to increase airway responsiveness in asthmatic patients (4) and enhance nasal cytokine secretion (5).

The methods of assessing exposure and disease status in observational studies, however, varied, and results have been inconsistent depending on the applied methods and potential confounders included (6–20). Methods varied from predominantly ecological designs to public traffic counts, modeled estimations of air pollutant levels, distance of homes to major roads, and self-reported traffic density as a measure of exposure.

In this article, which is based on the second survey (1999/2000) of the multiple cross-sectional study ISAAC (International Study of Asthma and Allergies in Childhood), conducted in Muenster, Germany, we describe the relationship between self-reported symptoms of asthma and allergies in children and self-reported truck density on street of residence as indicator of air pollution, controlled for several potential confounders. Information was assessed by ISAAC written and video questionnaires. ISAAC Phases I and II results on the relationship between traffic density, asthma and allergic rhinitis were reported in previous studies (10, 18, 20).

Methods

Study subjects and data collection

The methods of the ISAAC Project worldwide and in Muenster (population = 265,600 inhabitants) have been described in detail elsewhere (21, 22). Briefly, the study comprises two surveys, conducted in 1994/1995 (Phase I) and 1999/2000 (Phase III), and completed with identical methodology and study instruments, to assess trends in the prevalence of wheezing and atopic symptoms in 6–7- and 13–14-yr-olds. A representative sample of schools in Muenster was drawn. Two grades, grade 1–2 and 7–9, with the highest proportion of students in the respective age groups were asked to participate.

Information for the younger age group was collected by parental report, while adolescent children were asked to complete the ISAAC written questionnaire themselves while present at school. In the latter age group, an additional video questionnaire, depicting five scenes of clinical symptoms of asthma, was administered. In our study, we analyzed two questions regarding the prevalence of wheezing during the last 12 months and the questions concerning the lifetime prevalence of severe asthma symptoms according to the video questionnaire. Positive answers to these two questions are presented as wheeze during the last 12 months or asthma according to the video questionnaire.

Consistent with previously published reports from the ISAAC project, we used the following core questions from the written questionnaire to define the health outcome, concerning the presence of wheezing or whistling in the chest in the past 12 months (22) and about the presence of rhinitis when the participant did not have a cold or flu in the past 12 months (23). Information related to a lifetime diagnosis of the two disorders was obtained from two questions about ever having had asthma or hay fever. We also considered the presence of nocturnal cough during the last 12 months according to the written and video questionnaire as outcome.

Information on traffic density on street of residence was collected with two questions: (i) frequency of trucks passing on the residential street on weekdays and (ii) the severity of traffic noise that forced participants to close the window (never/rare/frequent/constant).

The self-assessment of traffic exposure via questionnaire was validated in a study, conducted in Munich, Germany (24). There was a strong correlation between self-reported truck traffic with public traffic counts and a less strong, but significant association between reports of traffic exposure and measures of outdoor NO_2, which were independent from an asthma diagnosis in the observed children.

Data analysis

The overall response (n = 7962) in the ISAAC Phase III survey was 82% in 6–7-yr-olds and 94% in 13–14-yr-olds. In 14 participants information on sex was missing and they were subsequently excluded. Consistent with earlier reports from Muenster (2, 18), we included only students with known German nationality, rendering a total of 7345 questionnaires for analysis.

Prevalence figures were calculated by dividing the number of participants who responded affirmatively to a question by the total number of participants. Inconsistencies between subsequent questions were not considered in accordance with ISAAC recommendations (22, 23).

As potential confounders we included the following variables: parental atopy, active smoking, passive exposure to smoking (ETS), heating with fossil fuels, birds and furry animals as pets, number of older siblings, own bedroom, living on a farm, and duration of living in the present dwelling. Parental atopy was defined as a history of asthma, hay fever, or atopic eczema in either one parent. Fossil fuels for heating included coal, oil, wood, and gas.

In the younger age group, information on two additional variables was solicited: (i) duration of exclusive breast feeding without supplementary food (<5 months/≥ 5 months) and (ii) the presence of molds or wet stains in the child's bedroom. Furthermore, information on exposure to ETS, contact to pets, heating energy source, own bedroom, living on a farm, and presence of molds during the first year of life were solicited in the younger age group, and their influence was investigated separately. We added each of the potential confounding variables separately to the model. In the younger age group, thus, two models were analyzed: one with present exposures and one with exposures during the first year of life.

Active smoking, ETS, and heating with fossil fuels, as potential confounders of similar air pollutants as compared to traffic, and parental atopy were kept in the model independently from their influence on the outcome parameter. Other variables were included in the final analysis if they changed the association by at least 10%. Finally, we also analyzed the interaction of some variables with traffic exposure.

We calculated prevalence ratios by performing a binomial regression with complementary log link function to assess correlates of truck traffic and traffic noise, as recommended for cross-sectional studies by several authors, e.g. (25). All analyses were done using SAS 8.02 statistical package.

Results

In the written questionnaire, 12-month wheezing was reported by 13.2% of the 6–7-yr-olds and 17.5% of adolescents, while 6.9% of the adolescents reported wheezing during the last 12 months in the video questionnaire. Asthma was reported in 4.4% and 7.8% in the written questionnaire, respectively, and in 4.9% obtained with the video questionnaire.

Most frequently, participants reported rare truck traffic (46.4% and 47.6% in the 6–7- and 13–14-yr-olds, respectively), while the majority of participants indicated that they had never experienced intense traffic noise, forcing them to close the windows. Constant truck traffic and constant traffic noise were rarely reported in both age groups. For further parameters and characteristics see Table 1. Tables 2–6 present the sex-adjusted and multivariate prevalence ratios (PR) between self-reported truck traffic and atopic symptoms and diagnoses with 95% confidence intervals (CI).

In 6–7-yr-olds, positive associations for wheezing during the last 12 months were found on the upper exposure levels. However, results did not reach statistical significance (Table 2).

In adolescents (Table 4), the association between self-reported truck traffic and 12-month wheezing was stronger than in 6–7-yr-olds, reaching statistical significance on some levels of exposure. The prevalence ratios were 1.29 (95% CI 0.98–1.70) for rare traffic, 1.33 (0.95–1.88) for frequent, and 1.81 (1.19–2.73) for constant truck traffic in boys and 1.28 (0.99–1.65), 1.54 (1.15–2.05), and 1.19 (0.76–1.86) in girls, respectively.

Positive associations with self-reported asthma (PR ranging from 0.89 to 1.40 in boys and from 0.90 to 1.78 in girls) were found for the younger students (present exposure, Table 3), while in 13–14-yr-olds no clear associations were observed (Table 5).

Reported truck traffic and rhinitis were strongly associated in 13–14-yr-olds, with significant results and a dose–response relationship in girls [PR = 1.23 (1.04–1.45), 1.27 (1.05–1.55), 1.57 (1.24–1.99)] and in boys [PR = 1.11 (0.93–1.33), 1.14 (0.90–1.44), 1.62 (1.24–2.11)] (Table 4), while the analysis of the younger age group revealed weaker and mostly non-significant associations (Table 2).

When stratifying symptomatic children with wheeze or rhinitis according to a diagnosis of asthma or hay fever, most associations became non-significant (results not shown). However, the associations with respiratory symptoms tended to be stronger in children without a diagnosis of asthma or hay fever in the older age group. Differences in associations between children with and without a diagnosis of hay fever or asthma were less pronounced in the younger age group.

The prevalence of nocturnal cough was positively associated with truck traffic in the older age group (particularly in boys, Table 6). However, most results were not statistically significant, when stratified according to sex. No associations between cough and truck traffic were seen for the younger age group (results not shown).

When the analyses were based on self-reported traffic noise, elevated and partially significant associations were observed in the older age group for wheezing and rhinitis. Asthma was somewhat elevated in 13–14-yr-old boys and in the 6–7-yr-olds, but results were not consistent and did not reach statistical significance (results not shown).

We found no positive effect of self-reported truck traffic or traffic noise on hay fever in both age groups.

We also calculated the linear trend for the association between self-reported truck traffic and atopic symptoms and diagnoses. A slightly stronger, though non-significant association between truck traffic and wheeze was seen for girls in the younger age group as compared to boys. In adolescents, a slightly stronger trend between truck traffic and wheeze was observed in boys (in both genders χ^2-test for trend $p < 0.05$).

Testing for confounding, only parental atopy and active smoking showed a stronger and more consistent confounding effect on some outcome or exposure levels. Together with passive smoking and type of fuel for heating they were adjusted for in the model. We did not observe effect modification between the traffic or noise variable and active or passive smoking, parental atopy, type of heating, or duration of living in the present dwelling with respect to the different outcome parameters.

Table 1. Selected characteristics of the study population; ISAAC Phase III (2000) in Muenster

	6–7-yr-olds (n = 3529)		13–14-yr-olds (n = 3816)	
	n	%	n	%
Sex				
Male	1863	52.8	1894	49.6
Female	1666	47.2	1922	50.4
Frequency of residential truck traffic (missing values)	(65)	(1.8)	(61)	(1.6)
Never	847	24.0	1087	28.5
Rare	1638	46.4	1818	47.6
Frequent	705	20.0	632	16.6
Constant	274	7.8	218	5.7
Severity of residential traffic noise (missing values)	(54)	(1.5)	(24)	(0.6)
Never	2473	70.1	2779	72.8
Rare	541	15.3	747	19.6
Frequent	277	7.9	166	4.4
Constant	184	5.2	100	2.6
Frequency of residential truck traffic – exposure during first year of life (missing values)	(84)	(2.4)	n/a	n/a
Never	799	22.6	–	–
Rare	1495	42.4	–	–
Frequent	764	21.7	–	–
Constant	387	11.0	–	–
Severity of residential traffic noise – exposure during first year of life (missing values)	(76)	(2.2)	n/a	n/a
Never	2187	62.0	–	–
Rare	588	16.7	–	–
Frequent	371	10.5	–	–
Constant	307	8.7	–	–
Wheezing during last 12 months (WQ) (missing values)	(43)	(1.2)	(71)	(1.9)
Yes	466	13.2	666	17.5
No	3020	85.6	3079	80.7
Wheezing during last 12 months (VQ) (missing values)	n/a	n/a	(52)	(1.4)
Yes	–	–	264	6.9
No	–	–	3500	91.7
Nocturnal cough during last 12 months (WQ) (missing)	(87)	(2.5)	(78)	(2.0)
Yes	560	15.9	881	(23.1)
No	2882	81.7	2857	74.9
Nocturnal cough during last 12 months (VQ) (missing)	n/a	n/a	(78)	(2.0)
Yes	–	–	552	14.5
No	–	–	3186	38.5
Asthma (WQ) (missing values)	(34)	(1.0)	(34)	(0.9)
Yes	156	4.4	298	7.8
No	3339	94.6	3484	91.3
Asthma (VQ) (missing values)	n/a	n/a	(48)	(1.3)
Yes	–	–	188	4.9
No	–	–	3580	93.8
Rhinitis during last 12 months (missing values)	(41)	(1.2)	(53)	(1.4)
Yes	578	16.4	1219	31.9
No	2910	82.5	2544	66.7
Hay fever (missing values)	(53)	(1.5)	(67)	(1.8)
Yes	211	6.0	897	23.5
No	3265	92.5	2852	74.7

WQ, written questionnaire; VQ, video questionnaire; n/a, not available.

Discussion

Our data show a positive association between self-reported truck traffic and wheezing and rhinitis during the last 12 months prior to the survey. For rhinitis and wheezing, the observed associations were stronger and statistically significant at the upper exposure levels in 13–14-yr-olds.

Our results are in line with the results from ISAAC Phase I in Muenster (18, 21), which was conducted with identical methods in 1994/1995, and those from the ISAAC pilot study in Bochum (17), with both reporting positive associations between truck traffic and current wheezing and allergic rhinitis among 13–14-yr-olds. Also, a study from Italy (19) observed a

Table 2. Prevalence ratios with 95% confidence intervals for the association between self-reported truck traffic and self-reported atopic symptoms (wheezing and rhinitis during the last 12 months) among 6–7-yr-olds

	Prevalence ratio*		Multivariate prevalence ratio†			
			Present exposure		Exposure during first year of life	
	Present exposure	Exposure during first year of life	Boys	Girls	Boys	Girls
Wheeze during last 12 months	n = 3486	n = 3486	n = 1777	n = 1590	n = 1767	n = 1584
No truck traffic	1.0	1.0	1.0	1.0	1.0	1.0
Rare truck traffic	0.86 (0.70–1.06)	0.93 (0.75–1.15)	0.81 (0.62–1.07)	1.01 (0.73–1.41)	0.80 (0.59–1.07)	1.17 (0.83–1.65)
Frequent truck traffic	0.99 (0.77–1.26)	1.06 (0.83–1.35)	0.96 (0.69–1.33)	1.09 (0.74–1.59)	0.96 (0.69–1.33)	1.31 (0.89–1.91)
Constant truck traffic	1.24 (0.91–1.68)	1.22 (0.92–1.62)	1.13 (0.74–1.71)	1.34 (0.85–2.13)	1.37 (0.97–1.95)	1.13 (0.69–1.84)
Rhinitis during last 12 months	n = 3488	n = 3488	n = 1785	n = 1585	n = 1776	n = 1579
No truck traffic	1.0	1.0‡	1.0	1.0	1.0‡	1.0
Rare truck traffic	1.13 (0.93–1.36)	1.06 (0.87–1.29)	1.10 (0.86–1.41)	1.09 (0.80–1.49)	0.86 (0.67–1.10)	1.21 (0.87–1.68)
Frequent truck traffic	1.29 (1.03–1.60)	1.09 (0.87–1.36)	1.10 (0.81–1.48)	1.49 (1.06–2.10)	0.87 (0.65–1.16)	1.29 (0.89–1.87)
Constant truck traffic	1.15 (0.85–1.56)	1.42 (1.11–1.81)	1.26 (0.87–1.82)	0.99 (0.59–1.67)	1.21 (0.89–1.65)	1.68 (1.12–2.52)

*Adjusted for sex.
†Adjusted for parental atopy, use of fossil fuels for heating, and passive smoking.
‡Chi-square test for trend $p < 0.05$.

Table 3. Prevalence ratios with 95% confidence intervals for the association between self-reported truck traffic and self-reported atopic diagnoses (asthma and hay fever) among 6–7-yr-olds

	Prevalence ratio*		Multivariate prevalence ratio†			
			Present exposure		Exposure during first year of life	
	Present exposure	Exposure during first year of life	Boys	Girls	Boys	Girls
Asthma	n = 3495	n = 3495	n = 1787	n = 1587	n = 1779	n = 1581
No truck traffic	1.0	1.0	1.0	1.0	1.0	1.0
Rare truck traffic	0.86 (0.59–1.28)	0.73 (0.50–1.07)	0.89 (0.55–1.47)	0.90 (0.47–1.73)	0.74 (0.45–1.21)	0.74 (0.40–1.36)
Frequent truck traffic	1.13 (0.73–1.76)	0.77 (0.49–1.20)	1.29 (0.74–2.25)	1.10 (0.51–2.34)	0.86 (0.48–1.52)	0.74 (0.35–1.55)
Constant truck traffic	1.57 (0.93–2.66)	1.08 (0.66–1.78)	1.40 (0.69–2.82)	1.78 (0.77–4.10)	1.34 (0.74–2.44)	0.84 (0.34–2.09)
Hay fever	n = 3476	n = 3476	n = 1776	n = 1580	n = 1767	n = 1574
No truck traffic	1.0	1.0	1.0	1.0	1.0	1.0
Rare truck traffic	0.93 (0.68–1.27)	0.85 (0.62–1.17)	0.82 (0.56–1.21)	1.0 (0.58–1.73)	0.87 (0.57–1.30)	0.58 (0.33–0.99)
Frequent truck traffic	0.95 (0.65–1.39)	0.84 (0.57–1.23)	0.89 (0.55–1.44)	1.14 (0.59–2.19)	0.83 (0.51–1.35)	0.62 (0.32–1.20)
Constant truck traffic	0.62 (0.33–1.16)	0.91 (0.57–1.43)	0.77 (0.38–1.53)	0.36 (0.08–1.51)	0.93 (0.53–1.64)	0.76 (0.35–1.65)

*Adjusted for sex.
†Adjusted for parental atopy, use of fossil fuels for heating, and passive smoking.

significant association between truck traffic and severe speech-limiting wheeze among children in urban centers when truck traffic was assessed via questionnaire.

Our results are also in accordance with various other studies that reported a positive association between traffic density and atopic symptoms or asthma, e.g. (11, 16). Contrary to our results, some studies did not find a positive relationship, though (15, 26).

Regarding hay fever, our results are in line with some studies (13, 27), while another study, contrary to our survey, found a positive association between traffic density and hay fever (11). However, the majority of those studies relied on other methods than self-report to estimate exposure to traffic, which may explain the difference in results between studies. In the study of Wilkinson et al. (26), for example, admission to the hospital was chosen as outcome parameter, and exposure was defined as proximity to major roads, choosing a high cut-off point at 150 m, which may be inappropriate, considering that other studies were looking at rather localized measures of exposure.

Advantages of our study are the large number of subjects, the complete registration of all students in the respective grades in the city of Muenster, and the high response rates.

However, our study has limitations. In the ISAAC survey, truck traffic exposure was only estimated through self-report. This might not

Table 4. Prevalence ratios with 95% confidence intervals for the association between self-reported truck traffic and self-reported atopic symptoms (wheezing and rhinitis during the last 12 months) among 13–14-yr-olds

	Prevalence ratio*		Multivariate prevalence ratio†			
			Written questionnaire		Video questionnaire	
	Written questionnaire	Video questionnaire	Boys	Girls	Boys	Girls
Wheeze during last 12 months	n = 3745	n = 3764	n = 1682	n = 1552	n = 1688	n = 1563
No truck traffic	1.0‡	1.0‡	1.0§	1.0§	1.0	1.0
Rare truck traffic	1.29 (1.08–1.53)	1.14 (0.86–1.53)	1.29 (0.98–1.70)	1.28 (0.99–1.65)	1.52 (0.96–2.40)	0.97 (0.64–1.48)
Frequent truck traffic	1.58 (1.29–1.94)	1.40 (0.99–1.98)	1.33 (0.95–1.88)	1.54 (1.15–2.05)	1.68 (0.96–2.92)	0.92 (0.54–1.57)
Constant truck traffic	1.57 (1.18–2.10)	1.81 (1.15–2.84)	1.81 (1.19–2.73)	1.19 (0.76–1.86)	1.74 (0.84–3.63)	1.25 (0.61–2.57)
Rhinitis during last 12 months	n = 3763	n/a	n = 1690	n = 1562	n/a	n/a
No truck traffic	1.0‡	–	1.0‡	1.0‡	–	–
Rare truck traffic	1.20 (1.06–1.34)	–	1.11 (0.93–1.33)	1.23 (1.04–1.45)	–	–
Frequent truck traffic	1.35 (1.17–1.55)	–	1.14 (0.90–1.44)	1.27 (1.05–1.55)	–	–
Constant truck traffic	1.69 (1.42–2.0)	–	1.62 (1.24–2.11)	1.57 (1.24–1.99)	–	–

*Adjusted for sex.
†Adjusted for parental atopy, active and passive smoking, and use of fossil fuels for heating.
‡Chi-square test for trend $p < 0.01$.
§Chi-square test for trend $p < 0.05$.
n/a = not available.

Table 5. Prevalence ratios with 95% confidence intervals for the association between self-reported truck traffic and self-reported atopic diagnoses (asthma and hay fever) among 13–14-yr-olds

	Prevalence ratio*		Multivariate prevalence ratio†			
			Written questionnaire		Video questionnaire	
	Written questionnaire	Video questionnaire	Boys	Girls	Boys	Girls
Asthma	n = 3782	n = 3768	n = 1697	n = 1569	n = 1688	n = 1563
No truck traffic	1.0	1.0	1.0	1.0	1.0	1.0
Rare truck traffic	1.07 (0.83–1.38)	1.07 (0.78–1.48)	1.07 (0.77–1.50)	0.84 (0.55–1.28)	1.12 (0.68–1.83)	0.94 (0.59–1.51)
Frequent truck traffic	1.14 (0.82–1.58)	0.83 (0.53–1.31)	1.0 (0.63–1.60)	1.04 (0.63–1.72)	0.82 (0.40–1.70)	0.60 (0.30–1.17)
Constant truck traffic	0.92 (0.54–1.56)	0.94 (0.49–1.82)	1.10 (0.56–2.16)	0.39 (0.12–1.25)	0.45 (0.11–1.87)	1.13 (0.50–2.55)
Hay fever	n = 3749	n/a	n = 1684	n = 1563	n/a	n/a
No truck traffic	1.0	–	1.0	1.0	–	–
Rare truck traffic	1.00 (0.88–1.14)	–	0.90 (0.75–1.07)	1.13 (0.92–1.40)	–	–
Frequent truck traffic	0.92 (0.77–1.10)	–	0.81 (0.63–1.05)	0.95 (0.72–1.25)	–	–
Constant truck traffic	0.97 (0.75–1.26)	–	0.88 (0.61–1.26)	1.04 (0.70–1.55)	–	–

*Adjusted for sex.
†Adjusted for parental atopy, active and passive smoking, and use of fossil fuels for heating.
n/a = not available.

Table 6. Prevalence ratios with 95% confidence intervals for the association between self-reported truck traffic and self-reported nocturnal cough among 13–14-yr olds

	Prevalence ratio*		Prevalence ratio†			
			Written questionnaire		Video questionnaire	
	Written questionnaire	Video questionnaire	Boys	Girls	Boys	Girls
Nocturnal cough during last 12 months	n = 3738	n = 3738	n = 1676	n = 1545	n = 1685	n = 1542
No truck traffic	1.0‡	1.0‡	1.0	1.0	1.0	1.0
Rare truck traffic	1.19 (1.04–1.38)	1.0 (0.83–1.20)	1.06 (0.83–1.35)	1.17 (0.97–1.42)	1.15 (0.81–1.64)	0.81 (0.64–1.02)
Frequent truck traffic	1.34 (1.13–1.59)	1.38 (1.11–1.72)	1.13 (0.83–1.53)	1.17 (0.93–1.47)	1.29 (0.83–2.01)	1.21 (0.93–1.56)
Constant truck traffic	1.52 (1.21–1.92)	1.34 (0.98–1.85)	1.50 (1.04–2.17)	1.07 (0.76–1.51)	1.62 (0.92–2.85)	0.93 (0.61–1.42)

*Adjusted for sex.
†Adjusted for parental atopy, active and passive smoking, and use of fossil fuels for heating.
‡Chi-square test for trend $p < 0.01$.

reflect the real traffic exposure in our population. Parents of symptomatic children and symptomatic adolescents may preferentially report traffic, leading to overestimation of the observed correlation. Nevertheless, an earlier study, conducted in Munich, Germany, demonstrated that parental assessment of truck traffic frequency correlated well with public traffic counts. This correlation was not influenced by the disease status of the observed children (24). However, the question on exposure during the first year of life was not validated in this study.

Using measurements of air pollutants, such as NO_2, black smoke, and particulate matter, to assess exposure is limited by the fact that these measurements are often recorded by a single monitoring station only, which might not reflect the pollutants' spatial distribution for the entire area. Mixture and distribution of pollutants are also influenced by meteorological, climatic, and geographical conditions, which cannot be controlled for entirely (28). Measuring exposure with a single monitoring station cannot be considered the 'gold' standard to assess traffic exposure; however, the associated problems are also inherent when multiple measuring stations are used, depending from the distance of the child's home to the respective station.

The importance of the relevance of truck traffic on respiratory symptoms, reduced lung function, and hospitalization for asthma is supported by results from the Netherlands (9, 16, 29) and the US (14), which all showed stronger associations between respiratory symptoms and counts of truck traffic rather than regular car traffic. Our traffic indicator focused on the residential exposure to truck traffic and can therefore be considered a crude marker for the relevant traffic exposure.

In our study, truck traffic frequency and traffic noise, a more general indicator of regular vehicle traffic, correlated positively in both age groups (Spearman rank coefficient $r = 0.59$ in 6–7-yr-olds and $r = 0.42$ in 13–14-yr-olds). However, associations between reported symptoms and diagnoses were less strong and consistent when traffic noise was employed.

This is in accordance with results from ISAAC Phase I (18), in which also traffic noise, as a general traffic indicator, was used, and with results from the ISAAC pilot study in Bochum (17), in which the authors constructed a more general marker from two questions concerning self-reported truck traffic density and the localization of the child's residence on a main or side street. Both studies observed weaker associations when the general traffic indicator was applied.

The investigated outcomes in our study were assessed by self-report in 13–14-yr-olds or parental report in 6–7-yr-olds, which might have biased our results. It may be that parents of symptomatic children chose to move away from busy streets, leading to a 'healthy resident' effect with weakened associations between allergic symptoms and traffic density. In this situation, results should differ for participants depending on the duration of living at the same residence (12, 27). In ISAAC Phase I, children who had been living at least 5 yr in the present dwelling showed stronger associations between truck traffic density and 12-month rhinitis than those who had been living in the same home for less than 5 yr (18). However, in ISAAC Phase III data, duration of living at the same address did not influence the results for wheezing, rhinitis, or atopic diagnoses as an effect modifier.

On the other hand, asthmatics could be more aware of potential hazardous environmental influences, which would lead to preferential reporting of symptoms and, therefore, stronger associations. Such an information bias could explain part of our results since the observed associations in our study were more marked for reported wheezing in adolescents and reported rhinitis in both age groups than for a diagnosis of asthma or hay fever. In addition, in our population most associations with wheeze and rhinitis appeared to be stronger in children without a diagnosis of asthma or hay fever as compared to children diagnosed with atopy. However, the numbers of symptomatic children with a positive diagnosis were small, and statistical significance was not reached in the majority of analyses. Nevertheless, our results are in agreement with other studies that reported increased respiratory symptoms in children exposed to traffic exhaust rather than clinical diagnoses determined by bronchial hyper-responsiveness testing (BHR) or levels of allergen-specific IgE (10, 13). These results support the hypothesis that components of air pollution may act primarily as non-specific irritative agents in the respiratory tract instead of inducing allergic inflammatory changes (7, 10).

We were able to test the influence of several potential confounders on the association between traffic density and atopic symptoms in the multivariate analyses. Seasonality and social status (SES) were not solicited and, therefore, could not be controlled for separately. However, a lot of the investigated factors can be considered collinear with SES (as indoor smoking, number of siblings, child's own bedroom).

A number of indoor factors (e.g. type of heating, smoking in the house) have been related to indoor pollution with NO_2 (11, 30). Unfortunately, we did not ask for more detailed information on type of heating or stove, or fuels used for cooking in the home.

In our data, a small influence of these variables on the association between atopic disease and traffic density has been noticed for active smoking, which was solicited only in 13–14-yr-olds on some levels of exposure. However, we also included passive smoking and type of heating (i.e., coal, oil, wood, or gas as energy source) in the multivariate model.

Unfortunately, we also did not solicit information about children's traffic exposure at school. Exposure at school may not add as much to children's total exposure if they spend most of their times at home. This was demonstrated in ISAAC phase II from Dresden (10) and also in a study from the UK, which examined exposure to local traffic in the locality of the children's schools and reported negative results (15). In contrast to these findings, a recent study from the Netherlands observed positive associations for exposure to truck traffic and various air pollutants, primarily in children with positive skin prick tests and increased bronchial hyper-responsiveness (29).

When the trend for associations between traffic density and atopic symptoms in adolescents was compared between girls and boys, the latter showed a slightly stronger trend between different levels of traffic density and reported wheeze as compared to girls, although the trend was statistically significant ($\chi^2 < 0.05$) in both sexes. In 6–7-yr-olds, the trend between traffic density and wheeze was slightly more marked in girls. In addition, we detected a stronger, but only marginally significant trend in the analysis of nocturnal cough and truck traffic among adolescent boys as compared to girls, while the younger age group showed no association with nocturnal cough in both sexes.

In large samples nonlinear associations may even turn significant in the absence of a linear relationship when the effect is based on the high risks of a small number of participants in the upper exposure categories. In our sample, only 5.7% of adolescents reported constant truck traffic. It is, therefore, possible that reporting heavy truck traffic is related to other unexplored conditions, such as differential reporting or environmental factors in the house that are driving the linear trend. While our finding that susceptibility to traffic-related pollution appears to be differential in the two age groups is noteworthy, reasons for the observed sex difference have yet to be elucidated.

In summary, we found associations suggesting that heavy truck traffic in residential areas might have a detrimental effect on the health of children. We employed questions of truck traffic density, which have been validated in a previous study. Our results are in line with the results found in ISAAC Phase I and the ISAAC pilot study in Bochum, which have been conducted with nearly identical methodology. However, this study does not explain the possible higher susceptibility for wheeze in males, and why this pattern is not observed in 6–7-yr-olds.

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References

1. Kay AB. Allergy and allergic diseases. First of two parts. N Engl J Med 2001: 344: 30–7.
2. Maziak W, Behrens T, Brasky TM, et al. Are asthma and allergies in children and adolescents increasing? Results from ISAAC phase I and phase III surveys in Münster, Germany. Allergy 2003: 58: 572–9.
3. Devalia JL, Rusznak C, Herdman MJ, Trigg CJ, Tarraf H, Davies RJ. Effect of nitrogen dioxide and sulphur dioxide on airway response of mild asthmatic patients to allergen inhalation. Lancet 1994: 344: 1668–71.
4. Nordenhall C, Pourazar J, Ledin MC, Levin JO, Sandstrom T, Adelroth E. Diesel exhaust enhances airway responsiveness in asthmatic subjects. Eur Respir J 2001: 17: 909–15.
5. Diaz-Sanchez D, Tsien A, Casillas A, Dotson AR, Saxon A. Enhanced nasal cytokine production in human beings after in vivo challenge with diesel exhaust particles. J Allergy Clin Immunol 1996: 98: 114–23.
6. Ponka A. Asthma and low level air pollution in Helsinki. Arch Environ Health 1991: 46: 262–70.
7. Braun-Fahrländer C, Vuille JC, Sennhauser FH, et al. Respiratory health and long-term exposure to air pollutants in Swiss schoolchildren. SCARPOL Team. Swiss Study on Childhood Allergy and Respiratory Symptoms with Respect to Air Pollution, Climate and Pollen. Am J Respir Crit Care Med 1997: 155: 1042–9.
8. Studnicka M, Hackl E, Pischinger J, et al. Traffic-related NO_2 and the prevalence of asthma and respiratory symptoms in seven year olds. Eur Respir J 1997: 10: 2275–8.
9. Brunekreef B, Janssen NA, de Hartog J, Harssema H, Knape M, van Vliet P. Air pollution from truck traffic and lung function in children living near motorways. Epidemiology 1997: 8: 298–303.
10. Hirsch T, Weiland SK, von Mutius E, et al. Inner city air pollution and respiratory health and atopy in children. Eur Respir J 1999: 14: 669–77.

11. Krämer U, Koch T, Ranft U, Ring J, Behrendt H. Traffic-related air pollution is associated with atopy in children living in urban areas. Epidemiology 2000: 11: 64–70.
12. Oosterlee A, Drijver M, Lebret E, Brunekreef B. Chronic respiratory symptoms in children and adults living along streets with high traffic density. Occup Environ Med 1996: 53: 241–7.
13. Wjst M, Reitmeir P, Dold S, et al. Road traffic and adverse effects on respiratory health in children. Br Med J 1993: 307: 596–600.
14. Lin S, Munsie JP, Hwang SA, Fitzgerald E, Cayo MR. Childhood asthma hospitalization and residential exposure to state route traffic. Environ Res 2002: 88: 73–8.
15. Venn AJ, Lewis SA, Cooper M, et al. Local road traffic activity and the prevalence, severity, and persistence of wheeze in school children: combined cross-sectional and longitudinal study. Occup Environ Med 2000: 57: 152–8.
16. van Vliet P, Knape M, de Hartog J, Janssen N, Harssema H, Brunekreef B. Motor vehicle exhaust and chronic respiratory symptoms in children living near freeways. Environ Res 1997: 74: 122–32.
17. Weiland SK, Mundt KA, Rückmann A, Keil U. Self-reported wheezing and allergic rhinitis in children and traffic density on street of residence. Ann Epidemiol 1994: 4: 243–7.
18. Duhme H, Weiland SK, Keil U, et al. The association between self-reported symptoms of asthma and allergic rhinitis and self-reported traffic density on street of residence in adolescents. Epidemiology 1996: 7: 578–82.
19. Ciccone G, Forastiere F, Agabiti N, et al. Road traffic and adverse respiratory effects in children. Occup Environ Med 1998: 55: 771–8.
20. Nicolai T, Carr D, Weiland SK, et al. Urban traffic and pollutant exposure related to respiratory outcomes and atopy in a large sample of children. Eur Resp J 2003: 21: 956–63.
21. Keil U, Weiland SK, Duhme H, Chambless L. The International Study of Asthma and Allergies in Childhood (ISAAC): objectives and methods; results from German ISAAC centers concerning traffic density and wheezing and allergic rhinitis. Toxicol Lett 1996: 86: 99–103.
22. The International Study of Asthma and Allergies in Childhood (ISAAC) Steering Committee. Worldwide variations in the prevalence of asthma symptoms: the International Study of Asthma and Allergies in Childhood (ISAAC). Eur Respir J 1998; 12: 315–35.
23. Strachan D, Sibbald B, Weiland S, et al. Worldwide variations in prevalence of symptoms of allergic rhinoconjunctivitis in children: the International Study of Asthma and Allergies in Childhood (ISAAC). Pediatr Allergy Immunol 1997: 8: 161–76.
24. Kuhlisch W, Hirsch T, Olunczek U, et al. Validierung von subjektiven Angaben zur Verkehrsexposition durch Verkehrszählungen, NO_2-Ausbreitungsmodellierungen und NO_2-Immissionsmessungen. [Validation of traffic self-reports by traffic counts, NO_2 dispersion models and NO_2 emission measurements.] Soz Praeventivmed 2002: 47: 116–23.
25. Zocchetti C, Consonni D, Bertazzi BA. Relationship between prevalence rate ratios and odds ratios in cross-sectional studies. Int J Epidemiol 1997: 26: 220–3.
26. Wilkinson P, Elliott P, Grundy C, et al. Case–control study of hospital admission with asthma in children aged 5–14 years: relation with road traffic in north west London. Thorax 1999: 54: 1070–4.
27. Wyler C, Braun-Fahrländer C, Kunzli N, et al. Exposure to motor vehicle traffic and allergic sensitization. The Swiss Study on Air Pollution and Lung Diseases in Adults (SAPALDIA) Team. Epidemiology 2000: 11: 450–6.
28. Monn C, Carabias M, Junker M, Waeber R, Karper M, Wanner HU. Small-scale spatial variability of particulate matter < 10 mm (PM_{10}) and nitrogen dioxide. Atmos Environ 1997: 31: 2243–7.
29. Janssen NAH, Brunekreef B, van Vlieth P, et al. The relationship between air pollution from heavy traffic and allergic sensitization, bronchial hyperresponsiveness, and respiratory symptoms in Dutch schoolchildren. Environ Health Perspect 2003: 111: 1512–8.
30. Ostro BD, Lipsett MJ, Mann JK, Wiener MB, Selner J. Indoor air pollution and asthma. Results from a panel study. Am J Respir Crit Care Med 1994: 149: 1400–6.