Road traffic and adverse respiratory effects in children

Giovannino Ciccone, Francesco Forastiere, Nera Agabiti, Annibale Biggeri, Luigi Bisanti, Elisabetta Chellini, Giuseppe Corbo, Valerio Dell'Orco, Paola Dalmasso, Tadeja Fatur Volante, Claudia Galassi, Silvano Piffer, Elisabetta Renzoni, Franca Rusconi, Piersante Sestini, Giovanni Viegi, and the SIDRIA collaborative group

Unit of Cancer Epidemiology, S Giovanni Battista Hospital and Center for Cancer Prevention (CPO), Piemonte, Torino, Italy
G Ciccone
P Dalmasso
T Fatur Volante

Department of Epidemiology, Regional Health Authority, Lazio, Roma, Italy
F Forastiere
N Agabiti
V Dell'Orco

Department of Statistics, University of Firenze, Italy
A Biggeri

Local Health Unit No 38, Milano, Italy
L Bisanti

Unit of Cancer Epidemiology, Careggi Hospital and Center for Study and Prevention on Cancer (CSPO), Firenze, Italy
E Chellini

Department of Respiratory Physiology, Catholic University, Roma, Italy
G Corbo

Regional Health Documentation Center (CDS), Emilia-Romagna, Bologna, Italy
C Galassi

Epidemiology Unit, Provincial Health Authority, Trento, Italy
S Piffer

Institute of Respiratory Diseases, University of Siena, Italy
E Renzoni
P Sestini

Department of Pediatrics, University of Milano, Italy
F Rusconi

CNR Institute of Clinical Physiology, Pisa, Italy
G Viegi

Correspondence to:
Dr Giovannino Ciccone, Unità di Epidemiologia dei Tumori, CPO Piemonte, Ospedale S Giovanni Battista, Via Santena 7, 10126 Torino, Italy.

Accepted 10 July 1998

Abstract
***Objectives*—To investigate the relation between traffic indicators in the area of residence and the occurrence of chronic respiratory disorders in children.**

***Methods*—A population based survey was conducted in 10 areas of northern and central Italy (autumn 1994 to winter 1995) in two age groups (6–7 and 13–14 years). Information on several respiratory disorders and on traffic near residences was collected with a questionnaire given to children and to their parents. The sample analysed included 39 275 subjects (response rate 94.4%). Outcomes were: (*a*) early (first 2 years of life) respiratory diseases, and (*b*) current respiratory disorders (asthma, wheeze, cough, or phlegm in the past year). Odds ratios (ORs) and 95% confidence intervals (95% CIs), adjusted for several potential confounders, were estimated from logistic regression models. Main results were stratified by level of urbanisation (metropolitan areas, other centres).**

***Results*—In the metropolitan areas, high frequency of lorry traffic in the street of residence was associated with significantly increased risks for many adverse respiratory outcomes. Among early respiratory diseases, the strongest associations were found for recurrent bronchitis (OR 1.69, 95% CI 1.24 to 2.30), bronchiolitis (1.74, 1.09 to 2.77) and pneumonia (1.84, 1.27 to 2.65), although no association was detected for episodes of wheezing bronchitis. All the current respiratory disorders were positively and consistently associated with frequency of lorry traffic, particularly the most severe bronchitic and wheezing symptoms: persistent phlegm for >2 months (1.68; 1.14 to 2.48), and severe wheeze limiting speech (1.86; 1.26 to 2.73). No or weaker associations with heavy vehicular traffic were detected in urban and rural areas and no increased risks were found in the whole sample with the reported traffic density in the zone of residence. After extensive evaluations, the potential of reporting bias seems unlikely.**

***Conclusion*—Exposure to exhausts from heavy vehicular traffic may have several adverse effects on respiratory health of children living in metropolitan areas, increasing the occurrence of lower respiratory tract infections early in life and of wheezing and bronchitic symptoms at school age.**

(*Occup Environ Med* 1998;**55**:771–778)

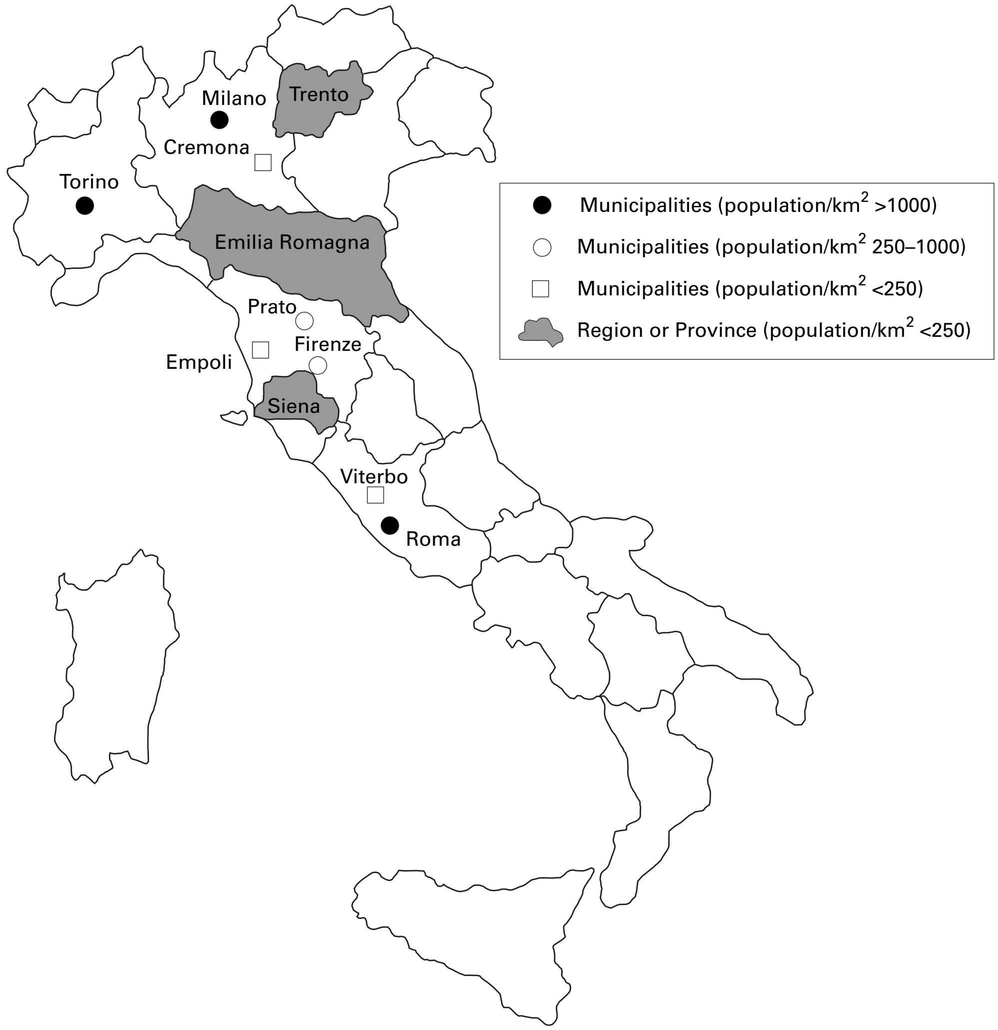
Keywords: traffic air pollution; diesel exhaust; childhood respiratory health

The role of outdoor air pollution on the respiratory health of children has been extensively investigated. Fine particulate matter and ozone have been associated with acute adverse effects. Long term exposure to air pollutants on chronic respiratory disorders has been less clearly backed up by evidence.[1–6]

A positive association between acute and chronic respiratory disorders in children and traffic air pollution has been recently reported with exposure indicators based on type and frequency of traffic flow around the residence of the subject.[7–13] However, negative studies have also been reported[14 15] and the interpretation of the results from the different investigations remains controversial.[16] Even in the case of overt asthma, an aetiological role of air pollution is debated,[17 18] although there is evidence of increasing severity of respiratory symptoms among already affected children.[1 2] The issue is of particular interest as outdoor air pollution has been claimed as one of the possible determinants of the reported increasing trend of childhood asthma, a disease for which genetic predisposition and immunological alterations are considered of key importance.[19 20]

To estimate the prevalence of respiratory problems in children, and to investigate the role of several potential risk factors, a large multicentre, population based, survey was conducted in Italy—studi italiani sui disturbi respiratori nell'infanzia e l'ambiente (SIDRIA).[21] The project is an extension of the international study on asthma and allergies in childhood (ISAAC).[22] This paper, with questionnaire based information, presents the results of an extensive analysis of the relation between indicators of road traffic pollution and a wide range of respiratory outcomes. Some of the health and exposure indicators have been validated against data obtained from other sources.

Methods
The survey was conducted during late autumn and winter 1994–5 (90% of subjects were contacted between November 1994 and January 1995) in 10 centres of northern and central Italy, varying in size, latitude, climate, and level



Map of SIDRIA centres in Italy.

of urbanisation (figure and table 1). Environmental data on air pollution indicate that the highest concentrations for most pollutants were recorded in the three largest cities covered by the survey (Torino, Milano, and Roma), with average yearly concentrations ranging between 50 and 70 μg/m^3 for particulate matter with mean aerodynamic diameter <10 μm (PM_{10}) and between 80 and 100 μg/m^3 for NO_2.

SUBJECTS

Two random samples of at least 1000 subjects per centre (or 3000 if prevalence of symptoms according to severity was also estimated) were drawn from the population of children and adolescents aged 6–7 and 13–14 (attending the first two grades of primary school and the last year of the middle school). Schools (both public and private) served as primary sampling units. Each centre listed the schools in the area, weighted them for the number of students and extracted a random sample of schools for each age group. In centres with a sampling fraction <25%, or with marked urban or geographic heterogeneity, the procedure was applied after stratification for local characteristics. A total sample of 42 159 subjects was obtained, representing an overall sampling fraction of 27% of the reference population. The response rate was high (94.4%), with little variation among centres (table 1). Out of 39 804 respondents, we excluded 529 subjects (1.3%) because their parents did not answer the main question about traffic density (analysed sample=39275).

DATA COLLECTION

Standardised self administered questionnaires were used. As well as the ISAAC items on asthma, rhinitis, and eczema,[22] the health section of the questionnaires included questions on: (*a*) medical diagnosis of asthma, with details on severity and treatment, (*b*) occurrence of other respiratory symptoms in detail, (*c*) medical history on episodes of respiratory diseases that occurred during the first two years of life. The questionnaires also included a section on many known or suspected risk factors for respiratory diseases. A questionnaire covering all these items was distributed to the children (6–7 years old) at school and filled in at home by their parents. Information from the adolescents was obtained through two questionnaires. One, mainly on current respiratory symptoms and on personal smoking habits, was addressed directly to them and filled in at school. The other was addressed to their

Table 1 Characteristics of the SIDRIA centres (ISAAC collaborative centres) and response rate by age group

Characteristics of centres			Response rate by age group (y)					
			6–7*		13–14†		Total	
Geographical area: centre	Administrative definition	Level of urbanisation	n	%	n	%	n	%
Northern Italy:								
Torino	Municipality	Metropolitan	1428	96.9	1209	94.9	2637	95.9
Milano	Municipality	Metropolitan	3616	96.1	3312	95.0	6928	95.5
Cremona	Local health unit	Urban or rural	1392	100.0	1195	98.8	2587	99.4
Trento‡	Province	Urban or rural	—	—	4086	87.2	4086	87.2
Emilia Romagna	Region	Urban or rural	4472	98.2	3938	97.1	8410	97.6
Central Italy:								
Firenze, Prato	6 Municipalities	Urban	1138	96.2	1141	94.1	2279	95.1
Empoli	Local health unit	Urban or rural	1434	91.0	1013	94.6	2447	92.8
Siena‡	Province	Urban or rural	—	—	1158	95.5	1158	95.5
Viterbo	Local health unit	Urban or rural	1230	97.5	875	90.8	2105	94.1
Roma	Municipality	Metropolitan	4027	94.5	3140	89.0	7167	91.7
Totals			18737	96.3	21067	92.8	39804	94.4

*Questionnaires filled in by parents.
†Both questionnaires (filled in by parents and by adolescents) available.
‡Only the 13–14 year olds included in the study.

parents and collected information about the medical history of the child and on exposures to several risk factors. Questions on traffic included (*a*) a subjective evaluation of the traffic density in the zone of residence (absent, low, intermediate, high); (*b*) the frequency of passing buses (0, 1, 2, or more routes) and lorries (never or seldom, sometimes in a day, often in a day) in the street of residence (question limited to those living in houses with windows facing the street). More details on the sampling design and on the questionnaires have been reported elsewhere.[21]

DATA VALIDATION

The validity of some key items of the health section of the questionnaire was evaluated in a pilot study on a sample of 106 adolescents. When compared with a reference diagnosis of current asthma made by a pneumologist (based on a positive history and a positive functional or challenge respiratory test), the questionnaire based definition of current asthma showed a sensitivity of 87% and a specificity of 92%.[23]

The validity of information on traffic was evaluated in Roma and Torino, with different approaches. In Roma, questionnaire data on lorry frequencies along a road significantly predicted outdoor NO_2 concentrations in 85 locations measured simultaneously with Palmes tubes over three 1-week periods in a year.[24] Average NO_2 concentrations ($\mu g/m^3$) were higher in streets where lorries often pass (mean (SD) 53 (10.9)) than in streets where lorries were reported not or seldom to pass (mean (SD) 43 (7.7)). In Torino the address of each respondent was coded and linked to objective data on traffic available from a survey conducted by the Local Administration in 80 selected streets. Evaluation of accuracy of the two indicators of heavy vehicular traffic (lorry frequency and number of bus routes) was possible for 250 subjects (out of 2147 reporting complete information on address and street traffic). The hourly median number of heavy vehicles passing in the street was better predicted by the three categories of the "lorry frequency" (never or seldom=98, sometimes=101, often=167) than by the "bus routes" categories (no routes=98, one route=149, two or more routes=116). Separate assessment for parents of symptomatic (cases) and non-symptomatic (controls) children showed no significant differences. According to the three categories of reported frequency, the hourly median numbers of lorries recorded in the streets were 71, 101, and 174 for cases and 104, 108, and 163 for controls, respectively. To investigate more in depth the possibility of a biased reporting of the traffic in the street, all cases (n=926) and controls (n=1221) were matched by address code. In this way, if the association is true, it should disappear when the comparisons are stratified for address code. Actually, the raw association between case-control status and the reported frequency of lorries (coded 1, 2, 3) showed a significant trend (odds ratio (OR) 1.12, p=0.0495). After matching cases and controls for address code (in 773 strata) the association disappeared, with an OR of 1.04 (p=0.729) (maximum likelihood estimates with exact method).[25] These evaluations suggest the absence of systematic differences between parents in reporting street traffic relative to the child's respiratory symptoms.

DATA ANALYSIS

The traffic indicators (of the zone or street of residence), with original categories of exposure, were analysed to assess the risk for: (*a*) early respiratory diseases (in the first two years of life), and (*b*) current respiratory conditions (in the past year).

Children with respiratory diseases that occurred during the first two years of life, as reported by parents (bronchitis, bronchiolitis, pneumonia, spastic laryngitis, and wheezing bronchitis), have been compared, both as a group (table 2) and for each specific condition (table 3) with a common reference group of children with a negative history for any of these conditions. As evaluation of traffic was requested only for the current address, this analysis was limited to children who had never changed residence.

Subjects were considered to have current respiratory problems if they (or their parents for the younger children) reported at least one out of the following eight lower respiratory tract symptoms included in the written questionnaire to occur during the past 12 months:

Table 2 Association between indicators of traffic air pollution and respiratory health in children, by level of urbanisation

	Early respiratory diseases (first 2 years of life)*									
	Urban or rural areas					Metropolitan centres				
	Total n	Cases %	OR	95% CI	p Value	Total n	Cases %	OR	95% CI	p Value
In the zone of residence										
Traffic density:										
Absent	2521	33.2	1	—		1061	36.2	1	—	
Low	5110	32.8	0.96	0.86 to 1.06		2375	35.5	1.00	0.86 to 1.17	
Moderate	3200	34.9	1.03	0.92 to 1.16		3214	33.8	0.94	0.81 to 1.10	
High	1220	37.6	1.09	0.95 to 1.28	0.1142	2017	37.7	1.09	0.93 to 1.29	0.3442
Total	12051	33.9				8667	35.4			
In the street of residence‡										
Number of bus routes:										
0	5327	34.1	1	—		3538	34.4	1	—	
1	1718	35.2	1.06	0.94 to 1.19		1371	37.6	1.18	1.04 to 1.35	
⩾2	1163	32.7	0.99	0.86 to 1.14	0.9284	875	36.0	1.12	0.96 to 1.31	0.0335
Daily lorry transit:										
Never or seldom	4750	34.0	1	—		3008	33.2	1	—	
Sometimes	2200	33.5	0.99	0.89 to 1.11		1854	36.1	1.14	1.01 to 1.29	
Often	1258	35.5	1.06	0.93 to 1.21	0.5498	922	40.9	1.39	1.19 to 1.62	0.0001
Total	8208	34.1				5784	35.4			

*Children with early (first two years of life) respiratory diseases *v* children with a negative medical history, analysis limited to children who never changed their residence.
†Children with current asthma, wheeze or bronchitic symptoms in the past year *v* children without these conditions in the same period, logistic regression estimates adjusted for study centre, age, sex, change of residence, mother's education, parental asthma, house crowding, bedroom characteristics (humidity or mould, bedding), gas cooking, heating systems, smoking (self, mother, father, or others), floor-level of the apartment.
‡Information not available for those living in houses without windows facing the street.
p Value is test for linear trend.

one or more wheezing episodes; shortness of breath with wheeze; wheeze with exercise; dyspnoea or dry cough or wheezing after exposure to pollens, pets, or house dust; nocturnal dry cough; morning chest tightness; persistent cough, and persistent phlegm (apart from colds). Subjects under treatment for medically diagnosed asthma were also considered current cases. Children with any current respiratory condition were compared, both as a group (table 2) and for each specific symptom (table 4), with a common reference group of healthy children, corresponding to those negative for all these conditions in the past year, with no exclusion.

Odds ratios and 95% confidence intervals (95% CIs) were estimated with multiple logistic regression models (SAS, version 6.12 for personal computer). Each model included age group and study centre (as stratification variables used in the sampling) and several potential confounders identified at the start: sex, change of residence (except for the analysis of early respiratory diseases), maternal education, parental asthma, house crowding, characteristics of the child's room (humidity or mould, presence of moquette or carpets, type of bedding), gas cooking, heating system, floor level of the apartment, smoking (self, of the mother, of the father, or of others). The level of urbanisation (metropolitan areas, other centres) was identified as a relevant risk modifier and the main results are presented stratified by this factor (table 2). For children living in metropolitan centres, analyses focusing on the relation between lorry transit in the street of residence and specific respiratory outcomes are reported in detail (table 3 and 4).

The goodness of fit of each selected model was evaluated by means of the Hosmer-Lemeshow χ^2 test with eight degrees of freedom.[26] As the residuals of each regression model did not seem to be correlated within school, no correction for clustered sample design has been used.

Results

Table 2 presents an overview of the association between the available traffic indicators and the respiratory health of the children (during the first 2 years of life and at the time of study), stratified by level of urbanisation.

The total number of children analysed according to the traffic density of the zone of residence (first section of the table) was 39 275, 20 718 (52.8%) of whom had lived all their life in the same house. Overall, only weak and inconsistent associations were detected according to traffic density. Detailed analyses with traffic density as the exposure indicator for specific early and current respiratory outcomes confirmed the absence of significant associations (data not shown, available upon request).

Information about traffic of heavy vehicles in the street of residence was available for 26 234 children living in houses with windows facing the street, 13 992 (53.3%) of whom had never moved home. As shown in the second section of table 2, positive associations between respiratory outcomes and indicators of heavy vehicular traffic, particularly of lorry frequency, were detected for children living in the metropolitan centres, but not in the less urbanised areas. In metropolitan centres, children living along streets with a frequent transit of lorries showed significantly increased risks of about 40% for respiratory diseases early in life (OR 1.39, 95% CI 1.19 to 1.62) and of 30% for current respiratory problems (OR1.29, 95% CI 1.15 to 1.45) compared with those living along streets with the lowest frequency of lorry transit. The effect of frequent heavy vehicular traffic on current symptoms seems to be specific, as the association was evident also among 3789 children living in zones where traffic density was described as absent or low. Out of 97 subjects living in streets with reported high lorry traffic, 58.8% showed current symptoms, corresponding to an OR of 1.70 (1.10 to 2.62). Results from detailed

Table 2 (continued)

Current respiratory conditions (past year)†									
Urban or rural areas					*Metropolitan centres*				
Total n	*Cases %*	*OR*	*95% CI*	*p Value*	*Total n*	*Cases %*	*OR*	*95% CI*	*p Value*
5028	42.5	1	—		2130	44.5	1		
9600	44.3	1.07	1.00 to 1.16		4606	44.6	0.93	0.83 to 1.04	
5952	46.4	1.13	1.04 to 1.23		6017	44.1	0.89	0.80 to 1.00	
2223	45.2	1.06	0.95 to 1.18	0.0512	3719	47.3	1.00	0.89 to 1.12	0.8988
22803	44.6				16472	45.0			
9825	44.4	1	—		6559	43.8	1	—	
3265	47.1	1.03	0.95 to 1.12		2703	46.7	1.10	1.00 to 1.21	
2189	48.5	1.03	0.94 to 1.14	0.3722	1693	48.2	1.16	1.03 to 1.29	0.0062
8994	44.5	1	—		5809	42.5	1	—	
4018	47.3	1.09	1.01 to 1.19		3403	47.3	1.21	1.10 to 1.32	
2267	46.8	1.01	0.92 to 1.12	0.2671	1743	50.1	1.29	1.15 to 1.45	0.0001
15279	45.5				10955	45.2			

analyses in metropolitan areas, based on reported transit of lorries, are shown in table 3 (for early respiratory diseases) and in table 4 (for current respiratory conditions). Table 3 presents the relation between the five conditions included in the medical history section of the questionnaire and the parent's evaluation of lorry frequency in the residential street. With the exception of wheezing bronchitis, all other diseases showed a positive association, with a significant trend by level of exposure. The strongest associations were between lorry traffic and lower respiratory tract infections: recurrent bronchitis (OR 1.69), bronchiolitis (OR 1.74) and pneumonia (OR 1.84). No relevant differences were found between age groups or sexes.

Table 4 indicates a consistent positive association between heavy vehicular traffic exposure and a wide range of respiratory complaints reported in the past year. All estimated ORs were positive; the ORs for the highest level of exposure were significantly increased, with excess risks between 20% and 90%; a consistent trend according to level of exposure was evident for most comparisons; children with more severe symptoms showed a general tendency towards higher risks. The association between current asthma and frequent passage of lorries was more evident for children with concurrent cough or phlegm symptoms (OR 1.70, 95% CI 1.11 to 2.61) than in those reporting only wheeze (OR 1.18; 0.90 to 1.55).

Overall, the difference in estimated risks between the two age groups was not significant. However, slightly higher risks in younger children were detected for most wheezing symptoms (particularly for severe wheeze limiting speech: OR 2.40, 1.24 to 4.66), and higher risks were found among adolescents for bronchitic symptoms (persistent phlegm lasting >2 months: OR 2.20, 1.24 to 3.90). Only slight, and non-systematic, differences were detected according to sex: among younger children most associations were higher in boys, whereas a reverse pattern, with a tendency towards higher risks for girls, is suggested among adolescents.

Detailed analyses performed according to the reported number of bus routes, an indicator showing weaker correlation to objective data on heavy traffic counts, gave similar, although less coherent, results (not shown, available upon request).

Table 3 Association between respiratory diseases in the first 2 years of life and frequency of daily lorry transit in the street of residence in the three metropolitan centres only (Torino, Milano, Roma)†*

		Frequency of daily lorry transit:							
		Never‡	*Sometimes*			*Often*			
Respiratory diseases (first 2 years of life)	*Total n*	*%*	*%*	*OR*	*95% CI*	*%*	*OR*	*95% CI*	*p Value†*
Bronchitis	1616	47.3	33.3	1.18	1.03 to 1.35	19.4	1.47	1.24 to 1.73	(0.0001)
>3 Episodes	318	44.6	32.7	1.17	0.89 to 1.53	22.6	1.69	1.24 to 2.30	(0.0032)
Pneumonia	199	46.7	29.1	1.03	0.73 to 1.45	24.1	1.84	1.27 to 2.65	(0.0134)
Bronchiolitis	154	45.5	37.0	1.52	1.05 to 2.18	17.5	1.74	1.09 to 2.77	(0.0073)
Spastic laringitis	340	47.3	35.3	1.30	1.01 to 1.67	17.3	1.43	1.04 to 1.97	(0.0151)
Wheezing bronchitis	390	52.3	33.8	1.14	0.90 to 1.45	13.8	1.02	0.74 to 1.40	(0.7323)
>3 Episodes	133	54.1	33.1	1.04	0.71 to 1.54	12.8	0.93	0.54 to 1.59	(0.7769)
None of the 5 diseases listed§	3737	53.7	31.7			14.6			

*Analysis limited to subjects who never changed their residence.
†Logistic regression estimates adjusted for: study centre, age, sex, mother's education, parental asthma, house crowding, bedroom characteristics (humidity or mould, bedding), gas cooking, heating systems, smoking (mother, father or others), floor level of the apartment.
‡Reference category.
§Common reference group. p Value is test for linear trend.

*Table 4 Association between current respiratory conditions (in the past 12 months) and frequency of daily lorry transit in the street of residence in the three metropolitan centres only (Torino, Milano, Roma)**

		Frequency of daily lorry transit:							
		Never†	Sometimes			Often			
Current respiratory conditions (past 12 months):	Total n	%	%	OR	95% CI	%	OR	95% CI	p Value
Current asthma	655	52.2	30.8	1.13	0.94 to 1.37	16.9	1.25	0.99 to 1.59	(0.0683)
With hospital admission	36	44.4	38.9	1.46	0.70 to 3.04	16.7	1.11	0.42 to 2.89	(0.5570)
Wheeze (at least 1 attack)	942	51.7	31.1	1.12	0.95 to 1.31	17.2	1.25	1.02 to 1.53	(0.0350)
Severe enough to limit speech	195	43.6	33.8	1.43	1.02 to 2.00	22.6	1.86	1.26 to 2.73	(0.0012)
Shortness of breath with wheeze (at least 1 attack)	701	49.9	31.8	1.18	0.98 to 1.42	18.3	1.34	1.07 to 1.68	(0.0134)
Wheeze with exercise	993	47.8	32.4	1.23	1.04 to 1.46	19.7	1.44	1.17 to 1.77	(0.0005)
Dyspnoea, dry cough or wheeze after exposure to pollens, pets, house dust	2120	51.2	32.5	1.20	1.06 to 1.36	16.3	1.18	1.01 to 1.38	(0.0065)
Nocturnal dry cough (apart from colds)	2403	48.0	33.5	1.26	1.13 to 1.41	18.5	1.34	1.17 to 1.54	(0.0001)
Morning chest tightness	577	49.2	32.9	1.26	1.03 to 1.54	17.8	1.31	1.02 to 1.69	(0.0122)
Persistent cough (apart from colds)	1634	47.8	32.7	1.26	1.11 to 1.44	19.5	1.49	1.27 to 1.74	(0.0001)
Lasting more than two months	158	48.1	31.0	1.15	0.79 to 1.65	20.9	1.47	0.96 to 2.24	(0.1216)
Persistent phlegm (apart from colds)	1663	47.0	32.8	1.28	1.12 to 1.46	20.3	1.60	1.35 to 1.87	(0.0001)
Lasting more than two months	190	43.7	34.2	1.38	0.99 to 1.93	22.1	1.68	1.14 to 2.48	(0.0103)
None of the 9 conditions listed‡	6004	55.6	29.9			14.5			

*Logistic regression estimates adjusted for: study centre, age, sex, change of residence, mother's education, parental asthma, house crowding, bedroom characteristics (humidity or mould, bedding), gas cooking, heating systems, smoking (self, mother, father or others), floor level of the apartment.
†Reference categories.
‡Common reference group.
p Value is test for linear trend.

Discussion

This study shows a positive association between indicators of air pollution from heavy vehicular traffic in the street of residence and a wide range of respiratory disorders in children living in highly urbanised areas. Exposed children more often reported wheeze, cough, and phlegm during the 12 months before interview and more frequent episodes of respiratory diseases early in life. Among the different outcomes analysed relative to frequency of lorries in the street of residence, those involving inflammation of the lower respiratory tract showed the strongest risks, whereas no association was found with early episodes of wheezing bronchitis. The other indicator of potential exposure to motor vehicle emissions (traffic density in the zone of residence) was not associated with either current or early respiratory disorders.

VALIDITY OF THE STUDY

As both exposure and health information were based on a questionnaire, validity of results needs to be carefully evaluated.

The study included a large population sample to minimise random errors. Also, the wide range of living conditions among the centres involved, and the high response rate, indicate that the results are representative and could be generalised. Information about symptoms included items derived from validated questionnaires used in previous epidemiological investigations[21 22] and some key questions were also preliminarily validated locally.[23] Internal consistency among traffic items in the questionnaire and the comparison with external sources of data indicate a satisfactory reliability of the information collected, particularly for the classification of the residential street according to frequency of lorry transit.[24]

In this type of study, reporting bias as a possible explanation of the results cannot be excluded with certainty. Parents of symptomatic children, particularly of those diagnosed with asthma, could have been more worried about the possible negative effects of environmental pollution and therefore be more prone to overestimate traffic density or to overreport respiratory conditions in their children. However, there are several indications that such possibilities are unlikely. (1) We found stronger effects of traffic exposure on symptoms other than asthma. (2) No or weaker associations were detected with reported traffic density in the zone of residence, probably a more subjective index of traffic exposure than frequency of lorries. (3) The association was also present among adolescents, for whom symptoms were self reported whereas traffic data were derived from their parents. (4) Evidence of positive and coherent results was limited to metropolitan areas, whereas a reporting bias is expected to affect results in the whole sample. (5) The specific association with heavy vehicular traffic in the street is present also for those reporting overall low traffic density in the zone of residence. (6) In one centre (Torino), comparisons of reported street traffic between parents of symptomatic and non-symptomatic children living along the same street suggest the absence of major biases. (7) It is also relevant that all the current symptoms reported in the questionnaires and all the diseases included in the medical history have been analysed and presented, without selection. Residual confounding by unmeasured exposures—such as pollens or other pollutants not directly derived from traffic—cannot be excluded. Nevertheless, the magnitude of residual confounding, if any, should be small, as many confounders have already been considered.

INTERPRETATION OF RESULTS

Children living in an urban environment are permanently exposed to background levels of several pollutants (particulate matter and nitrous dioxide), with a pattern of space (decreasing from the inner city towards the suburbs) and time (higher concentrations during the day) variation. Also, subjects living near busy roads may also experience peaks of exposure to the emissions of circulating cars, as well as diesel exhausts from heavy vehicles. Measures of type and volume of traffic flow near home, focusing directly on sources, may be reliable indicators of level of exposure to an urban mixture of pollution, even in the absence of direct measurements of specific pollutants.

Recently, seven cross sectional studies used indicators of the traffic flow near the residence to investigate the association with respiratory health.[7 8 10–14] All but one[14] found positive associations for inflammatory and asthma-like symptoms, but only one[11] reported a positive, statistically weak, finding for asthma diagnosed by a physician. A case-control study in Birmingham, UK found that children admitted to hospital for asthma were significantly more exposed to traffic flow than either hospital or population controls.[9] Another case-control study, based on the lists of two inner city general practices in London, UK, failed to show any difference in the distance of the residence from main roads, comparing patients with a prescription for asthma drugs in the preceding year with a sample of all other patients who had had a consultation for other reasons in the same period.[15]

In our study, a coherent association between the health outcomes and the indicator of lorry traffic in residential streets was evident, although no increased risks were detected with the average traffic index in the zone of residence. This may reflect (*a*) a specific and more dangerous effect of diesel exhausts (the fuel of heavy vehicles in Italy); (*b*) higher volumes of vehicular traffic of all types in streets where lorries often go (higher levels of exposure to all pollutants derived from traffic); (*c*) a reduced misclassification of exposure (a more reliable evaluation of traffic density) when street, rather than zone of residence, is used in the questions. However, the specific role of diesel exhausts suggested by our results is consistent with findings from other studies. In Bochum, Germany[10] the slope of the ORs for wheezing and allergic rhinitis was higher when the exposure indicator was lorry traffic on the street of residence, compared with estimates based on a more complex index which combined the lorry traffic with the type of street (main road or side street). Another German study conducted in Munster[12] showed consistently higher risks of respiratory symptoms relative to diesel exposure indexes than to more general indicators of car traffic—such as traffic noise. Recent results from Holland indicated that chronic respiratory symptoms,[13] and reduced lung functions in children,[27] were more strongly associated with lorry traffic (and to black smoke as a proxy of diesel exhausts) than to automobile traffic (and to nitrogen dioxide, more correlated with total traffic density). Diesel exhausts are relevant contributors to PM_{10} which is toxic to the respiratory mucosa, causing inflammatory reactions and predisposing to infections of the lower respiratory tract.[1 2 28] It seems to be plausible that in the three more urbanised centres included in our survey, with background yearly mean concentrations of PM_{10} between 50 and 70 μg/m^3, roadside exposure may reach concentrations high enough to produce adverse effects on respiratory health. There is also evidence of a positive interaction between diesel particles and environmental allergens.[29–31] Heavy vehicles, as a major source of tyre debris in the sediment and of tyre dust in suspended particulate, could be directly responsible of latex allergy.[32]

Stronger associations were found for children reporting severe asthmatic and bronchitic symptoms in the year before interview (table 4). This finding may simply reflect a better clinical specificity of the groups (less false positive subjects included), but also could be interpreted as confirmation of an increased susceptibility of the sicker children to environmental pollution.[1–4 28] The relation with lorry traffic resulted in a significantly increased OR (1.70) in those reporting asthma with persistent cough and phlegm, whereas the association was weaker (OR 1.18), and not significant, for those reporting only asthma. A positive association of air pollution, particularly suspended particulate and acid aerosols, with bronchitis, but not with asthma, has been reported in the six cities study[33] and recently confirmed by two other studies conducted in 10 communities in Switzerland[5] and in 24 communities of the United States and of Canada.[6] In our data, early wheezing bronchitis did not show any association with traffic indicators, by contrast with other respiratory diseases reported during the first 2 years of life. This finding is in agreement with the finding that most infants with transient wheeze during viral respiratory infections do not show a particular susceptibility for environmental factors and do not share increased risk of asthma or atopy later in life.[34] Overall, these results suggest a more important role of air pollution in increasing the risk of lower respiratory tract infections than in the aetiology of asthma.

Although no age related differences were detected for respiratory diseases during the first 2 years of life, children of 6–7 showed slightly higher risks than adolescents, particularly of wheezing symptoms. Even if the traffic flow in the residential street may be a more satisfactory indicator for schoolchildren than for adolescents, who spent more time away from home, an increased susceptibility of young children to poor air quality is possible, as was suggested by Pope's data on hospital admissions relative to particulate air pollution.[35] The suggested higher susceptibility of girls to air pollution related to traffic reported by some authors[11 13 36] is partially supported by our data only in the 13–14 age group, whereas a reverse pattern, with a tendency towards higher risks among boys, is suggested in the younger children.

The relatively weak associations reported by this study may imply an underestimation of the true risks, as (*a*) the reference category of children living in streets without heavy traffic cannot be considered unexposed (especially in metropolitan areas); and (*b*) random errors in the classification of subjects with respect to both exposure and disease tend to dilute the effects. As the exposure to heavy vehicle exhausts involves a large proportion of children living in large cities, from a public health perspective this problem may be relevant if evaluated in terms of attributable risks. Even assuming no underestimation of risks this exposure may be responsible for at least 10% of all the respiratory outcomes analysed.

In summary, this study provides support for the hypothesis that air pollution from traffic (particularly from heavy vehicles) is potentially hazardous to the health of children, increasing the risk for a wide range of adverse respiratory effects, particularly in centres with high levels of urbanisation. If confirmed, these results suggest that a stricter regulation of traffic in residential areas, at least of heavy vehicles, may be an effective preventing measure for the respiratory health of children.

This work was funded by the Italian Regional Health Authorities. The SIDRIA Collaborative Group is grateful to all schoolchildren and to their parents for participation and to the teachers for helpful collaboration. We specially thank all the physicians and staff members of the Local Health Units of the National Health Service for their important work in the collection of data. We also thank Professors Benedetto Terracini and Franco Merletti for helpful comments to the manuscript and Dr Elaine Wright for revision of the text. Useful comments were provided from the reviewers.

Appendix

SIDRIA (Studi Italiani sui Disturbi Respiratori nell' Infanzia e l'Ambiente) collaborative group: G Ciccone, A Camerlengo, M Bugiani, P Dalmasso, F Faggiano, T Fatur Volante, C Magnani, P Natale, P Piccioni (Torino); L Bisanti, V Gianelle, F Rusconi, S Sideri (Milano); S Piffer, F Filippetti, E Nava (Trento); M Biocca, E Canossa, B Cavalchi, D Cervino, S Cattani, E De'Munari, M Deserti, S Ferro, F Fortezza, F Frigo, C Galassi, M Martini, P Mazzali, L Paterlini, R Sogni, M Zanini (Emilia Romagna); E Chellini, L Agati, E Barletta, A Biggeri, G Bini, M Bini, L Chetoni, D Grechi, A Seniori Costantini (Firenze); E Renzoni, P Sestini (Siena); G Viegi (Pisa); F Forastiere, N Agabiti, G Corbo, V Dell'Orco, S Mallone, C Micera, P Palermo, G Pallotti, G Piras, R Pistelli (Roma); E Salera (Frosinone); D Argentini, G Chiarucci (Latina).

1 Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society. Health effects of outdoor air pollution (part I). *Am J Respir Crit Care Med* 1996;**153**:3–50.
2 Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society. Health effects of outdoor air pollution (part II). *Am J Respir Crit Care Med* 1996;**153**:477–98.
3 Bates DV. The effects of air pollution on children. *Environ Health Perspect* 1995;**103**:49–53.
4 Lebowitz MD. Epidemiological studies of the respiratory effects of air pollution. *Eur Respir J* 1996;**9**:1029–54.
5 Braun-Fahrländer C, Vuille JC, Sennhauser FH, *et al*. Respiratory health and long-term exposure to air pollutants in Swiss schoolchildren. *Am J Respir Crit Care Med* 1997;**155**:1042–9.
6 Dockery DW, Cunningham J, Damokosh AI, *et al*. Health effects of acid aerosols on North American children: respiratory symptoms. *Environ Health Perpspect* 1996;**104**:500–5.
7 Nitta H, Sato T, Nakai S, *et al*. Respiratory health associated with exposure to automobile exhaust. I. Results of cross-sectional studies in 1979, 1982, and 1983. *Arch Environ Health* 1993;**48**:53–8.
8 Wjst M, Reitmeir P, Dold S, *et al*. Road traffic and adverse effects on respiratory health in children. *BMJ* 1993;**307**:596–600.
9 Edwards J, Walters S, Griffiths RK. Hospital admissions for asthma in pre-school children: relationship to major roads in Birmingham, United Kingdom. *Arch Environ Health* 1994;**49**:223–7.
10 Weiland SK, Mundt KA, Ruckmann A, Keil U. Self-reported wheezing and allergic rhinitis in children and traffic density on street of residence. *Ann Epidemiol* 1994;**4**:243–7.
11 Osterlee A, Drijver M, Lebret E, *et al*. Chronic respiratory symptoms in children and adults living along streets with high traffic density. *Occup Environ Med* 1996;**53**:241–7.
12 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.
13 Van Vliet P, Knape M, De Hartog J, *et al*. Motor vehicle exhausts and chronic respiratory symptoms in children living near major freeways. *Environ Res* 1997;**74**:122–32.
14 Waldron G, Pottle B, Dodd J. Asthma and the motorways—one District's experience. *J Publ Health Med* 1995;**17**:85–9.
15 Livingstone AE, Shaddick G, Grundy C, *et al*. Do people living near inner city main roads have more asthma needing treatment? Case-control study. *BMJ* 1996;**312**:676–7.
16 Department of Health Committee on the Medical Effects of Air Pollutants. *Asthma and outdoor air pollution*. London: HMSO, 1995.
17 Strachan DP. Commentary: traffic exposure and asthma: problems of interpretation. *BMJ* 1996;**312**:677.
18 Sears MR. Epidemiology of childhood asthma. *Lancet* 1997;**350**:1015–20.
19 Seaton A, Godden DJ, Brown K. Increase in asthma: a more toxic environment or a more susceptible population? *Thorax* 1994;**49**:171–4.
20 Cookson WO, Moffatt MF. Asthma: an epidemic in absence of infection? *Science* 1997;**275**:41–2.
21 SIDRIA Collaborative Group. Asthma and respiratory symptoms in 6–7 year-old Italian children: gender, latitude, urbanisation and socio-economic factors. *Eur Respir J* 1997;**10**:1780–6.
22 Asher MI, Keil U, Anderson HR, *et al*. International study of asthma and allergies in childhood (ISAAC): rationale and methods. *Eur Respir J* 1995;**8**:483–91.
23 Pistelli R, Fuso L, De Rosa M, *et al*. *A validation of the ISAAC bronchial symptoms video questionnaire. European Respiratory Society Annual Congress*. Stockholm: ERS, 1996.
24 Dell'Orco V, Forastiere F, Rosini A, *et al*. Use of nitrogen dioxide passive dosimeters to evaluate car exhaust exposure in a study of respiratory health in children. In: *Convention in long-range transboundary air pollution. Health effects of ozone and nitrogen oxides in an integrated assessment of air pollution*. Leicester, UK: Institute for Environmental Health, 1997: 112–4.
25 Metha C, Patel N, Gray R. On computing an exact confidence interval for the common odds ratio in several 2x2 contingency tables. *Journal of the American Statistical Association* 1985;**80**:969–73.
26 Hosmer DW, Lemeshow S. *Applied logistic regression*. New York: John Wiley, 1989:140–5.
27 Brunekreef B, Janssen NAH, de Hartog J, *et al*. Air pollution from truck traffic and lung function in children living near motorways. *Epidemiology* 1997;**8**:298–303.
28 Dockery DW, Pope CA. Acute respiratory effects of particulate pollution. *Ann Rev Public Health* 1994;**15**:107–32.
29 Molfino NA, Slutsky AS, Zamel N. The effects of air pollution on allergic bronchial responsiveness. *Clin Exp Allergy* 1992;**22**:667–72.
30 Pierson WE, Koening JQ. Respiratory effects of air pollution on allergic disease. *J Allergy Clin Immunol* 1992;**90**:557–66.
31 Frew AJ, Salvi SS. Diesel exhaust particles and respiratory allergy. *Clin Exp Allergy* 1997;**27**:237–9.
32 Miguel AG, Cass GR, Weiss J, *et al*. Latex allergens in tire dust and airborne particles. *Environ Health Perspect* 1996;**104**:1180–6.
33 Dockery DW, Speizer FE, Stram DO, *et al*. Effects of inhalable particles on respiratory health of children. *Am Rev Respir Dis* 1989;**139**:587–94.
34 Martinez FD, Wright AL, Taussig LM, *et al*, and the Group Health Medical Associates. Asthma and wheezing in the first six years of life. *N Engl J Med* 1995;**332**:133–8.
35 Pope CA. Respiratory hospital admission associated with PM_{10} pollution in Utah, Salt Lake, and Cache Valleys. *Arch Environ Health* 1991;**46**:90–7.
36 Pershagen G, Rylander E, Norberg S, *et al*. Air pollution involving nitrogen dioxide exposure and wheezing bronchitis in children. *Int J Epidemiol* 1995;**24**:1147–53.