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RESPIRATORY HEALTH PROBLEMS IN ADOLESCENTS LIVING NEAR MAIN ROADS IN THE UPPER SILESIAN INDUSTRIAL ZONE, POLAND

MICHAŁ SKRZYPEK[1], MAŁGORZATA KOWALSKA[2], JOANNA KASZNIA-KOCOT[3], ELŻBIETA M. CZECH[1], and EWA NIEWIADOMSKA[1]

Medical University of Silesia, Katowice, Poland
[1] School of Public Health in Bytom, Department of Biostatistics
[2] Medical Faculty in Katowice, Department of Epidemiology
[3] School of Public Health in Bytom, Department of Epidemiology

Abstract
Objectives: This study explores the association between self-reported exposure to traffic-related air pollution and respiratory health symptoms, as well as lung functions and skin prick tests in adolescents living in the vicinity of main roads. **Material and Methods:** The data in the study were acquired using a cross-sectional study conducted between 2004–2005 in Chorzów (Silesia, Poland) among adolescents (N = 936) aged 13–15 years, attending junior high schools. Adverse respiratory health symptoms and exposure to traffic-related air pollution were determined on the basis of a questionnaire. Moreover, all children underwent spirometry and skin prick tests. Multivariable logistic regression with multiple imputation for missing data was used to assess the prevalence of adverse respiratory symptoms in relation to self-reported exposure to traffic-related air pollution, adjusted for socio-economic and environmental factors. **Results:** Among respiratory tract diseases, asthma and allergic rhinitis associations were statistically significant (OR = 2.16, 95% CI: 1.12–4.15 and OR = 1.69, 95% CI: 1.08–2.64, respectively). Likewise, among respiratory disorders, statistically significant associations were found in the case of wheezes and dyspnea attack (OR = 1.58, 95% CI: 1.10–2.26 and OR = 2.39, 95% CI: 1.56–3.66, respectively), with respect to the vicinity of the main road. Living in the area with high traffic intensity was statistically significantly associated with a higher prevalence of asthma and wheezes (OR = 2.31, 95% CI: 1.22–4.39 and 1.48, 95% CI: 1.09–2.01, respectively). The results obtained did not confirm the relationship between the adopted way of exposure to traffic-related air pollution and lung function indices or skin prick tests. **Conclusions:** Results of the study suggest that children living in the area with intense traffic are more likely to develop respiratory disorders. Moreover, the vicinity of a main road as well as traffic intensity could be suitable in assessing the relationship between road transport and potential health problems among exposed inhabitants. Int J Occup Med Environ Health. 2019;32(4):553–67

Key words:
lung volume measurements, respiratory diseases, adolescents, skin prick test, transportation, vehicles

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Corresponding author: Michał Skrzypek, Medical University of Silesia, School of Public Health in Bytom, Department of Biostatistics, Piekarska 18, 41-902 Bytom, Poland (e-mail: mskrzypek@sum.edu.pl).

INTRODUCTION

Data gathered by the WHO show that respiratory diseases remain one of the most important threats to health in Europe, especially among children [1]. Numerous publications suggest that adverse respiratory health effects in children are related to their exposure to ambient air pollution, especially in the urban environment [2–10]. There are many sources of outdoor air pollution in Europe (including the Silesian Agglomeration). The most important are vehicles, industry and power plants [11]. Moreover, residential heating by using coal furnaces during the winter season is another clear contributor [12].

Although Europe's air quality is slowly improving, fine particulate matter ($PM_{2.5}$) and nitrogen oxides (NO_x) from vehicles remain a serious public health concern [13]. However, the relationship between traffic-related air pollution and health consequences has not been adequately explained. This may be due to either the use of different models of exposure, different populations studied (i.e., children or adults) or the main sources of pollution. There are several studies indicating the intense car traffic as a potential risk factor for respiratory diseases and disorders [14–22]. However, such a relationship was not confirmed by other studies [9,23–25]. In addition, one of the recent WHO reports on contaminated sites and public health has pointed out the co-occurrence of hazard related to industrial pollution and the increasing intensity of road transport [26].

The Silesian Agglomeration (the south part of Poland) is one of the post-industrial regions of Europe with a relatively high number of inhabitants and an increasing number of vehicles [13,27]. Recently published data suggest an increase in the prevalence of childhood asthma in the Silesian Agglomeration area [28].

The aim of this study was to assess the prevalence of respiratory diseases and disorders, as well as the sensitization and lung functions, in adolescents living in the vicinity of the main roads in Chorzów, the second most populated city in the Silesian Agglomeration, with almost 3500 inhabitants/km^2 [29].

MATERIAL AND METHODS

The data were obtained from a cross-sectional study of children's respiratory health and allergic diseases, conducted in 2004–2005 in Chorzów. Children aged 13–15 years, attending all junior high schools (gimnazjum), were invited to participate in the study (N = 4520). The response rate among the participants was 25% (N = 1130).

The research protocol used the following methods: a questionnaire interview, a medical examination, spirometry, and skin prick testing. The questionnaire, based on the International Study of Asthma and Allergies in Childhood (ISAAC) and the Central European Study of Air Pollution and Respiratory Health (PHARE/CESAR) programs, and validated by the Institute of Occupational Medicine and Environmental Health [30,31], was filled out by parents or legal guardians of the children involved in the study. Spirometry was performed by a fully trained researcher. Lung function measurements, including forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1), percent predicted FEV_1, peak expiratory flow (PEF), and mid-expiratory flow (MEF_X) at 25–75% of FVC, were obtained with an autocalibrated ultrasonic flow-sensing spirometer (EasyOne, ndd Medical Technologies, Inc. Zurich, Switzerland).

Skin prick tests were carried out with the following allergens: cockroach (*Blatella germanica*), dogs' and cats' fur, mixed grass pollen, mixed weed pollen, tree pollen (*Corylus avellana, Betula alba*), moulds (*Alternaria tenuis*, *Cladosporium herbarum*, *Aspergillus fumigatus*), house dust and flour mites (*Dermatophagoides pteronyssinus*, *Dermatophagoides farinae*), as well as storage mites (*Acarus siro*, *Tyrophaus putrecentiae*, *Lepioglyphus destructor*), and histamine as positive and 0.9% sterile saline as negative control. The tests were interpreted within 15–20 min after they were performed. The positive result of the skin prick test was defined as a wheal ≥ 3 mm diameter [32].

The study was conducted with the approval of the Bioethical Committee of the Medical University of Silesia, No. NN-013-03/03. Among all the respondents, spirometry and skin prick tests were conducted on 961 (85%) children. However, 25 records were eventually removed due to missing data representing exposure to traffic-related air pollution. Thus, the final database contained 936 records.

The exposure assessment of traffic-related air pollution was based on responses to the following questions:

1. Describe the road near the place of your residence, with 7 possible response options: a highway, a main road in the city, a regional road between 2 cities, a main road in the city district, a main road in the housing estate, and a side road.
2. How often do cars pass by the road near the place of your residence, apart from the weekend, with 4 possible response options: never, rarely, frequently, and almost all day.

The authors defined 2 surrogates of exposure to traffic-related air pollution, namely the higher exposure from the "main road" if the response was at least "a regional road between 2 cities" to the first question, and "high traffic intensity" if the response was "almost all day" to the second question. Such definitions of the surrogates of exposure are plausible because the previously published results confirmed the relationship between proximity to the road and elevated concentrations of particulate matter and ozone [33,34].

Adverse health effects in children were determined on the basis of responses to the questions on ever doctor-diagnosed asthma, ever doctor-diagnosed spastic bronchitis, current (within last 12 months) and ever asthma medication use, current (within last 12 months) and ever chest wheeze, current (within last 12 months) and ever dyspnea attack, current (within last 12 months) and ever runny nose, current (within last 12 months) persistent cough, and ever doctor-diagnosed allergic rhinitis.

Categorical variables were presented as frequencies and percentages. Continuous variables were expressed as the mean and standard deviation (SD), or as median and quartiles. The assumption of normality was verified by the Shapiro-Wilk test. Categorical variables were compared using the χ^2 test. The Student's t-test and the Mann-Whitney U test were used to assess group differences for normally and non-normally distributed continuous variables, respectively. The association between traffic exposure and adverse health effects was analyzed by means of multivariable logistic regression.

The scope of the health effects analyzed by means of logistic regression included the following medical diagnosis: asthma and spastic bronchitis, wheezes, dyspnea attack, runny nose, and allergic rhinitis. The following confounders were controlled in the analysis: gender, body mass index (BMI), maternal employment, exposure to environmental tobacco smoke (ETS) at home, type of heating (coal-based or central), traces of moisture or moulds in the place of residence, and parental allergy. Age was intentionally omitted in the logistic regression because of the homogeneity of age (13–15 years old).

In order to minimize bias due to some missing data in the scope of the explanatory variables in the logistic regression model, multiple imputation under missing at random (MAR) assumption was used. The MAR assumption was checked with the "missingPattern" SAS macro [35]. The imputation technique was performed by means of the fully conditional specification (FCS) method. To evaluate parameter estimates of the logistic regression, 20 imputed data sets were used, while the number of burn-in iterations was set to 100. Results of the logistic regression were expressed as the odds ratio (OR) with 95% confidence interval (95% CI). The statistical significance level was set at $\alpha = 0.05$ criterion. Statistical analyses were conducted using the SAS statistical software package, version 9.4 (SAS Institute Inc., Cary, North Carolina, USA).

RESULTS

According to the self-reported assessment of exposure to traffic-related air pollution, the vicinity to the main

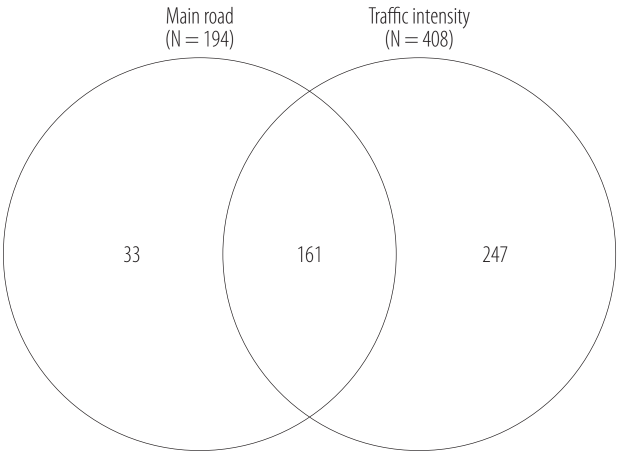


Figure 1. Children exposed to traffic-related air pollution, living in the Chorzów city, according to the defined surrogates of exposure in the cross-sectional study conducted in 2004–2005 in Chorzów (Silesia, Poland), involving adolescents (N = 936) aged 13–15 years, attending junior high schools – Venn diagram

road was the place of residence of 194 (20.7%) children, while 408 (43.6%) children lived in the area with high traffic intensity. The interaction between these 2 surrogates of exposure to traffic-related air pollution is presented in the Venn diagram (Figure 1).

Descriptive characteristics of the participants are presented separately in Table 1 for the 2 surrogates of exposure to traffic-related air pollution. There were slightly more girls (55.1%) than boys in the studied group. Most of the children were from moderately educated families. Mothers of 51% of the children completed at least high school education, and the majority of them were employed (83.1%). Household smoking was significantly frequent (65.6%) in the study group. Most of the houses where the children lived had coal-based heating (60.8%), and the traces of moistures or moulds were present in half of them. A higher socio-economic status of parents was more common in the area with lower exposure to traffic-related air pollution, whereas coal-based heating and traces of moisture or mould were more frequent in the area with higher exposure to traffic-related air pollution.

The prevalence of respiratory health problems in children and their association with self-reported exposure to traffic-related air pollution are shown in Table 2. The most frequent respiratory tract disorder in the study population was runny nose (> 40%), while asthma was reported in 5% of the children. The analysis performed by the authors showed that respiratory health problems occurred more frequently in children living in the vicinity of a main road. Evidently, spastic bronchitis and runny nose were not statistically significant. Similarly, children living in the area with high traffic intensity often reported respiratory health problems, but statistically significant association was observed only for asthma, current and ever chest wheezes, dyspnea attack, ever runny nose, and current persistent cough.

Table 3 displays lung function and skin prick tests in children, and their comparison between the groups defined by self-reported exposure to traffic-related air pollution. The mean FVC, FEV_1 and percent predicted FEV_1 amounted to M±SD = 3.62±0.72 l, 3.19±0.62 l and 88.7±7.9%, respectively. Interestingly, all the analyzed pulmonary function indices did not differ significantly between the exposed and unexposed group.

The authors also conducted sensitivity analysis, excluding children with prior asthma diagnosis and children with current asthma medication use. The obtained results did not differ from those presented here (data not shown).

Almost half of the children (47.1%) showed sensitization to at least 1 of the tested allergens (Table 3). The most frequent sensitization was to house dust mites (30.9%), followed by flour mites (26.6%) and grass pollen (21.9%). Boys were more likely than girls to have positive skin prick tests only in the case of grass pollen (25.7% vs. 18.8%, respectively; p = 0.01) and flour mites (30.2% vs. 23.6%, respectively; p = 0.02).

In addition, a comparison between the exposed and unexposed group did not reveal any statistically significant differences in the prevalence of sensitization, with 1 exception, namely the positive skin prick test to *Cladosporium herbarum*. Sensitivity to *Cladosporium herbarum* was more

Table 1. Characteristics of adolescents (N = 936) aged 13–15 years, attending junior high schools, according to exposure to traffic-related air pollution in the cross-sectional study conducted in 2004–2005 in Chorzów (Silesia, Poland)

Characteristics	Subjects							
	total (N = 936)	missing	living in the vicinity of a main road		p	traffic intensity near the place of residence		p
			no (N = 742)	yes (N = 194)		low (N = 528)	high (N = 408)	
Gender (female) [n (%)]	516 (55.1)	–	403 (54.3)	113 (58.2)	0.33	287 (54.4)	229 (56.1)	0.59
Age [years] (Me (Q1–Q3))	14.2 (13.6–14.8)	–	14.2 (13.6–14.8)	14.3 (13.7–14.9)	0.19	14.1 (13.6–14.8)	14.2 (13.7–14.9)	0.10
Anthropometric measures [M±SD]								
height [cm]	163.2±8.5	–	163.3±8.4	162.7±8.9	0.38	163.3±8.7	163.1±8.3	0.74
weight [kg]	54.3±10.5	–	54.6±10.4	53.2±11.0	0.12	54.6±10.3	53.9±10.7	0.30
BMI	20.3±3.0	–	20.4±3.0	20.0±3.1	0.13	20.4±3.0	20.1±3.1	0.24
Socio-economic status [n (%)]								
education (high school and above)								
maternal	469 (50.9)	14 (1.5)	388 (52.8)	81 (43.3)	**0.02**	295 (56.2)	174 (43.8)	**< 0.01**
paternal	308 (34.0)	29 (3.1)	255 (35.2)	53 (29.1)	0.12	196 (38)	112 (28.6)	**< 0.01**
employment								
maternal	776 (83.1)	2 (0.2)	621 (83.8)	155 (80.3)	0.25	448 (85.2)	328 (80.4)	**0.05**
paternal	882 (94.4)	2 (0.2)	700 (94.6)	182 (93.8)	0.67	502 (95.3)	380 (93.4)	0.21
Indoor environment [n (%)]								
current environmental tobacco smoke	614 (65.6)	–	490 (66)	124 (63.9)	0.58	333 (63.1)	281 (68.9)	0.06
heating system (coal based)	537 (60.8)	52 (5.6)	294 (41.4)	53 (30.5)	**0.01**	215 (42.2)	132 (35.3)	**0.04**
traces of moisture/moulds	440 (49.4)	46 (4.9)	338 (47.8)	102 (55.7)	0.06	231 (45.9)	209 (54)	**0.02**
fur animals	581 (62.7)	9 (1.0)	460 (62.6)	121 (63)	0.91	316 (60.3)	265 (65.8)	0.09
Family history of allergy [n (%)]								
parental allergy	187 (20.0)	–	151 (20.4)	36 (18.6)	0.58	107 (20.3)	80 (19.6)	0.8

Bolded – statistically significant difference.

Table 2. The frequency of respiratory health problems according to exposure to traffic-related air pollution in the cross-sectional study conducted in 2004–2005 in Chorzów (Silesia, Poland) among adolescents (N = 936) aged 13–15 years, attending junior high schools

Respiratory health problems	Subjects [n (%)]						
	total	living in the vicinity of a main road		p	traffic intensity near the place of residence		p
		no	yes		low	high	
Ever diagnosed with asthma	45 (4.8)	29 (3.9)	16 (8.2)	**0.01**	16 (3.0)	29 (7.1)	**< 0.01**
Ever diagnosed with spastic bronchitis	105 (11.2)	76 (10.2)	29 (14.9)	0.06	51 (9.7)	54 (13.2)	0.09
Asthma medication use							
current	58 (6.2)	39 (5.3)	19 (9.8)	**0.02**	29 (5.5)	29 (7.1)	0.31
ever	109 (11.7)	75 (10.1)	34 (17.5)	**< 0.01**	55 (10.4)	54 (13.2)	0.18
Chest wheeze							
current	117 (12.5)	78 (10.5)	39 (20.1)	**< 0.01**	49 (9.3)	68 (16.7)	**< 0.01**
ever	230 (24.6)	168 (22.6)	62 (32.0)	**< 0.01**	111 (21.0)	119 (29.2)	**< 0.01**
Dyspnea attack							
current	59 (6.3)	37 (5.0)	22 (11.3)	**< 0.01**	22 (4.2)	37 (9.1)	**< 0.01**
ever	121 (12.9)	78 (10.5)	43 (22.2)	**< 0.01**	56 (10.6)	65 (15.9)	**0.02**
Runny nose							
current	376 (40.2)	285 (38.4)	91 (46.9)	**0.03**	198 (37.5)	178 (43.6)	0.06
ever	409 (43.7)	313 (42.2)	96 (49.5)	0.07	215 (40.7)	194 (47.5)	**0.04**
Current persistent cough	76 (8.1)	52 (7.0)	24 (12.4)	**0.01**	33 (6.3)	43 (10.5)	**0.02**
Ever diagnosed with allergic rhinitis	121 (12.3)	87 (11.7)	34 (17.5)	**0.03**	63 (11.9)	58 (14.2)	0.30

Bolded – statistically significant difference.

Table 3. Lung function and skin prick tests according to exposure to traffic-related air pollution (N = 936) in the cross-sectional study conducted in 2004–2005 in Chorzów (Silesia, Poland) among adolescents (N = 936) aged 13–15 years, attending junior high schools

Variable	Subjects: total	Subjects: living in the vicinity of a main road – no	Subjects: living in the vicinity of a main road – yes	p	Subjects: traffic intensity near the place of residence – low	Subjects: traffic intensity near the place of residence – high	p
Lung function (M±SD)							
FVC [l]	3.62±0.72	3.63±0.71	3.59±0.77	0.48	3.62±0.71	3.62±0.74	0.91
FEV_1 [l]	3.19±0.62	3.20±0.61	3.17±0.65	0.51	3.20±0.62	3.19±0.62	0.81
$\%FEV_1$	88.70±7.90	88.61±7.75	89.06±8.45	0.48	88.78±7.94	88.61±7.86	0.76
FEV_1/FVC [%]	88.57±7.34	88.55±7.40	88.63±7.11	0.90	88.70±7.30	88.40±7.39	0.55
PEF [l/s]	6.11±1.29	6.11±1.27	6.11±1.35	0.99	6.14±1.30	6.07±1.27	0.36
MEF [l/s]							
MEF_{25}	5.54±1.24	5.54±1.23	5.58±1.25	0.68	5.59±1.26	5.49±1.21	0.25
MEF_{50}	4.17±1.05	4.17±1.05	4.14±1.05	0.72	4.18±1.07	4.15±1.02	0.60
MEF_{75}	2.27±0.79	2.29±0.80	2.20±0.76	0.16	2.29±0.82	2.25±0.76	0.44
$MEF_{25–75}$	3.72±0.97	3.73±0.97	3.67±0.98	0.44	3.72±0.98	3.72±0.95	0.97
Prick tests [n (%)]							
any antigen	441 (47.1)	351 (47.3)	90 (46.4)	0.82	251 (47.5)	190 (46.6)	0.77
mixed grass pollen	205 (21.9)	159 (21.4)	46 (23.7)	0.49	116 (22.0)	89 (21.8)	0.95
mixed weed pollen	164 (17.5)	129 (17.4)	35 (18)	0.83	94 (17.8)	70 (17.2)	0.80
Betula alba	77 (8.2)	59 (8.0)	18 (9.3)	0.55	48 (9.1)	29 (7.1)	0.27
Corylus avellana	61 (6.5)	48 (6.5)	13 (6.7)	0.91	34 (6.4)	27 (6.6)	0.91
Alternaria tenuis	63 (6.7)	47 (6.3)	16 (8.2)	0.34	35 (6.6)	28 (6.9)	0.89
Cladosporium herbarum	26 (2.8)	15 (2.0)	11 (5.7)	**0.01**	14 (2.7)	12 (2.9)	0.79
Aspergillus fumigatus	17 (1.8)	12 (1.6)	5 (2.6)	0.37	9 (1.7)	8 (2.0)	0.77
house dust mites	289 (30.9)	225 (30.3)	64 (33)	0.47	157 (29.7)	132 (32.4)	0.39
flour mites	249 (26.6)	199 (26.8)	50 (25.8)	0.77	141 (26.7)	108 (26.5)	0.94
Acarus siro	140 (15)	112 (15.1)	28 (14.4)	0.82	79 (15.0)	61 (15)	1.00
Tyrophagus putrescentiae	108 (11.5)	85 (11.5)	23 (11.9)	0.88	57 (10.8)	51 (12.5)	0.42
Lepidoglyphus destructor	106 (11.3)	79 (10.6)	27 (13.9)	0.20	58 (11.0)	48 (11.8)	0.71
cockroach	51 (5.5)	39 (5.3)	12 (6.2)	0.61	29 (5.5)	22 (5.4)	0.95
dogs' fur	50 (5.3)	36 (4.9)	14 (7.2)	0.19	26 (4.9)	24 (5.9)	0.52
cats' fur	90 (9.6)	65 (8.8)	25 (12.9)	0.08	44 (8.3)	46 (11.3)	0.13

FEV_1 – forced expiratory volume in 1 s; $\%FEV_1$ – percent predicted FEV_1; FEV_1/FVC – ratio of FEV_1 to FVC; FVC – forced vital capacity; MEF – mid-expiratory flow; PEF – peak expiratory flow.
Bolded – statistically significant difference.

frequent in children living within the vicinity of a main road than in children living farther from a main road (5.7% vs. 2.0%, respectively; p = 0.01).

The authors performed multivariable logistic regression to assess the association between selected adverse health effects and the surrogates of exposure to traffic-related air pollution, with adjustment to the following confounders: gender, BMI, maternal employment, exposure to environmental tobacco smoke at home, type of heating, traces of moisture or moulds in the place of residence, and parental allergy (Tables 4 and 5). A higher prevalence of asthma, wheezes, dyspnea attack, and allergic rhinitis remained statistically significant in children living in the vicinity of a main road, while asthma, wheezes, and dyspnea attack remained statistically significant among children living in the area with high traffic intensity, after adjustment for confounders. Wheezes were more common in boys than in girls. Higher BMI was related to a more frequent diagnosis of asthma, spastic bronchitis and allergic rhinitis. Exposure to ETS at home was associated with a higher prevalence of spastic bronchitis, ever experienced wheezes, and dyspnea attack. Asthma and spastic bronchitis, as well as wheezes and dyspnea attack, were more frequent in children living in houses with the coal-based heating system. Traces of moisture or moulds in the place of residence were associated with a higher prevalence of ever experienced wheezes and runny nose. Additionally, children were more likely to have dyspnea attack or runny nose, and allergic rhinitis, when their parents declared allergy.

DISCUSSION

Public interest on the impact of ambient air quality on the population health, especially on the respiratory system in children, leads to many protests in Poland each year. Current data from the European Environment Agency (EEA) indicate that a significant share of fine dust, nitrogen oxides, ozone and carbon monoxide in air pollution is related to car traffic [36]. It is not without significance that traffic emission also contributes to polycyclic aromatic hydrocarbons (PAHs) pollution, including benzo(a)pyrene, which has a higher concentration in Poland [36]. The best exposure measurements are necessary to assess the causal relationship between the observed health phenomena and exposure to this risk factor, but in the case of a lack of direct or individual measurements of such exposure, it is possible to use an indirect route. In environmental epidemiology studies, it is common to use the distance to the place of residence from sources of hazard pollutant emissions, including roads with high traffic intensity, as an exposure measure [37]. Recent studies have indicated that higher exposure to carbon monoxide, fine particulate matter or black smoke, which are typical ambient air pollutants from transportation, affects people living in the vicinity of roads with heavy traffic in the Upper Silesian industrial zone [21].

The aim of the study was to assess the prevalence of respiratory diseases and disorders, as well as lung functions, in adolescents living in the vicinity of main roads in one of the biggest cities in the Silesian Agglomeration.

The obtained results suggest that a indirect measurement of exposure, expressed by the declared place of residence in the vicinity of a main road or a road with high intensity traffic, could be useful to describe the risk of being ever diagnosed with asthma, and chest wheeze or dyspnea attack being ever declared by parents, among children living in Chorzów (Tables 4 and 5). Moreover, the frequency of all the health outcomes presented in Table 2 was higher in those adolescents who lived close to a main road or a road with a high density of traffic intensity. These results are consistent with earlier data from the Upper Silesian region [21], as well as with other published observations, where self-reported data of exposure to traffic-related air pollution were also used [38–42].

A recent study has indicated that analyses of the relationship between pro-inflammatory effects of ambient air pollution and asthma should be based on the concentration of

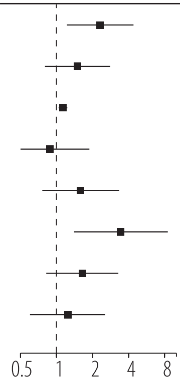
Table 4. The association between exposure to traffic-related air pollution, expressed as living in the vicinity of a main road, and adverse respiratory health effects, adjusted for confounders; results of the multivariable logistic regression with multiple imputation, performed in the cross-sectional study conducted in 2004–2005 in Chorzów (Silesia, Poland) among adolescents (N = 936) aged 13–15 years, attending junior high schools

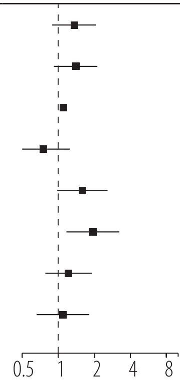
Variable	Subjects ever diagnosed with					
	asthma		spastic bronchitis		chest wheeze	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Main road	2.16 (1.12–4.15)	**0.02**	1.53 (0.96–2.46)	0.08	1.58 (1.10–2.26)	**0.01**
Gender (male)	1.47 (0.79–2.74)	0.22	1.40 (0.92–2.13)	0.11	1.43 (1.05–1.95)	**0.02**
Body mass index (BMI)	1.13 (1.04–1.23)	**< 0.01**	1.10 (1.03–1.17)	**< 0.01**	1.02 (0.97–1.08)	0.34
Maternal employment	0.87 (0.41–1.86)	0.72	0.75 (0.45–1.25)	0.27	1.08 (0.72–1.62)	0.72
Environmental tabacco smoke (ETS)	1.71 (0.82–3.58)	0.15	1.64 (1.01–2.66)	**0.04**	1.51 (1.07–2.12)	**0.02**
Heating system (coal-based)	3.32 (1.35–8.18)	**0.01**	1.86 (1.11–3.12)	**0.02**	1.62 (1.14–2.28)	**0.01**
Traces of moisture/moulds	1.73 (0.87–3.43)	0.12	1.24 (0.79–1.96)	0.34	1.42 (1.03–1.96)	**0.03**
Parental allergy	1.28 (0.62–2.62)	0.50	1.10 (0.66–1.82)	0.71	1.50 (1.04–2.15)	**0.03**

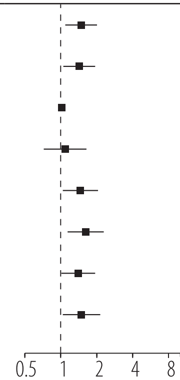
Variable	Subjects ever diagnosed with					
	dyspnea attack		runny nose		allergic rhinitis	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Main road	2.39 (1.56–3.66)	**< 0.01**	1.35 (0.97–1.87)	0.07	1.69 (1.08–2.64)	**0.02**
Gender (male)	1.03 (0.69–1.54)	0.87	1.09 (0.83–1.42)	0.54	1.30 (0.88–1.92)	0.20
Body mass index (BMI)	1.01 (0.95–1.08)	0.77	1.04 (1.00–1.09)	0.06	1.09 (1.02–1.15)	**0.01**
Maternal employment	1.11 (0.66–1.87)	0.70	0.99 (0.69–1.42)	0.95	0.72 (0.43–1.18)	0.19
Environmental tabacco smoke (ETS)	1.60 (1.02–2.52)	**0.04**	1.22 (0.92–1.62)	0.18	1.05 (0.69–1.61)	0.81
Heating system (coal-based)	1.81 (1.13–2.89)	**0.01**	1.23 (0.92–1.65)	0.16	1.24 (0.81–1.91)	0.33
Traces of moisture/moulds	1.44 (0.94–2.22)	0.10	1.31 (0.99–1.74)	0.06	0.89 (0.59–1.36)	0.60
Parental allergy	2.21 (1.43–3.41)	**< 0.01**	2.24 (1.61–3.11)	**< 0.01**	2.36 (1.54–3.61)	**< 0.01**

Table 5. The association between exposure to traffic-related air pollution, expressed as traffic intensity near the place of residence, and adverse respiratory health effects, adjusted for confounders; results of the multivariable logistic regression with multiple imputation, performed in the cross-sectional study conducted in 2004–2005 in Chorzów (Silesia, Poland) among adolescents (N = 936) aged 13–15 years, attending junior high schools

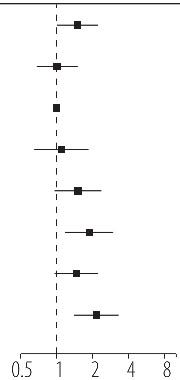
Variable	Subjects ever diagnosed with					
	asthma		spastic bronchitis		chest wheeze	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Traffic intensity	2.31 (1.22–4.39)	**0.01**	1.36 (0.89–2.06)	0.15	1.48 (1.09–2.01)	**0.01**
Gender (male)	1.50 (0.80–2.80)	0.20	1.40 (0.92–2.12)	0.11	1.43 (1.05–1.94)	**0.02**
Body mass index (BMI)	1.13 (1.04–1.23)	**< 0.01**	1.10 (1.03–1.17)	**< 0.01**	1.02 (0.97–1.08)	0.36
Maternal employment	0.88 (0.41–1.88)	0.74	0.75 (0.45–1.25)	0.27	1.09 (0.72–1.64)	0.68
Environmental tabacco smoke (ETS)	1.59 (0.76–3.33)	0.22	1.59 (0.98–2.58)	0.06	1.46 (1.04–2.05)	**0.03**
Heating system (coal-based)	3.44 (1.40–8.49)	**0.01**	1.95 (1.17–3.23)	**0.01**	1.62 (1.14–2.29)	**0.01**
Traces of moisture/moulds	1.64 (0.82–3.28)	0.16	1.22 (0.78–1.91)	0.39	1.40 (1.01–1.94)	**0.04**
Parental allergy	1.24 (0.60–2.54)	0.57	1.09 (0.66–1.81)	0.73	1.49 (1.04–2.14)	**0.03**

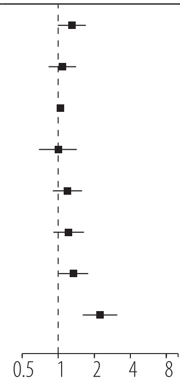


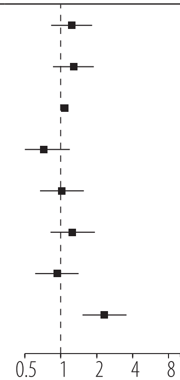




Variable	Subjects ever diagnosed with					
	dyspnea attack		runny nose		allergic rhinitis	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Traffic intensity	1.49 (1.01–2.21)	**0.05**	1.30 (0.99–1.70)	0.06	1.23 (0.83–1.83)	0.29
Gender (male)	1.01 (0.68–1.50)	0.95	1.08 (0.83–1.41)	0.57	1.28 (0.86–1.89)	0.22
Body mass index (BMI)	1.00 (0.94–1.07)	0.90	1.04 (1.00–1.09)	0.07	1.08 (1.02–1.15)	**0.01**
Maternal employment	1.10 (0.65–1.85)	0.72	1.00 (0.69–1.43)	0.98	0.72 (0.44–1.19)	0.20
Environmental tabacco smoke (ETS)	1.51 (0.96–2.37)	0.07	1.19 (0.90–1.58)	0.23	1.02 (0.67–1.56)	0.91
Heating system (coal-based)	1.88 (1.18–2.98)	**0.01**	1.22 (0.91–1.64)	0.18	1.25 (0.82–1.93)	0.30
Traces of moisture/moulds	1.46 (0.96–2.23)	0.08	1.34 (1.01–1.78)	**0.04**	0.93 (0.61–1.41)	0.74
Parental allergy	2.15 (1.40–3.30)	**< 0.01**	2.23 (1.60–3.11)	**< 0.01**	2.32 (1.52–3.55)	**< 0.01**







total emission from transportation, rather than on individual pollutants like PM (particulate matter) or PAHs [43]. Moreover, results of the ESCAPE study have confirmed the deleterious effect of air pollution on asthma incidence in adults [44]. It is worth mentioning that cohort studies have reported no significant association between air pollution exposure and childhood asthma prevalence in 5 European birth cohorts [45], and they do not show a consistent association between chronic bronchitis symptoms and current traffic-related air pollution in adult European populations [46].

Unlike other research studies [47–50], the results presented by the authors did not confirm a statistically significant association between residing in the vicinity of the area with intense traffic and lung function indices, or the frequency of positive skin prick tests, in the studied children, except *Cladosporium herbarum* (Table 3). On the one hand, these findings could be explained by the labile course of asthma in young people and the fact that the examination of lung functions was performed only once. Likewise, it cannot be excluded that the observed elevated frequencies of adverse respiratory health effects in children living close to the main road were due to over-reporting of traffic intensity [51,52].

An important determinant of a child's health status could be the socio-economic status of his/her family, including the level of parental education or employment [53]. Results of a simple analysis suggested that a higher level of maternal and paternal education was statistically significantly associated with lower environmental exposure in children (traffic-related air pollution). However, the multivariable analysis did not confirm a significant association between the available socio-economic status factors and health outcomes in children.

There are some limitations of the study, the first being that cross-sectional design has known limits [54,55]. Moreover, due to the lack of direct traffic measurements in the Chorzów city, additional bias could be introduced by the use of self-reported exposure to traffic-related air pollution [51,52]. It is worth mentioning that, according to the data provided by the general traffic measure in Poland for the year 2005, the average daily traffic on national roads in the Silesian Voivodeship was 13 433, and it was mainly (70%) the passenger car traffic [13]. Consequently, the low response rate (25%) may be an issue. People with respiratory health symptoms are more likely to participate in such surveys [56], which could cause self-selection bias towards a higher prevalence of the analyzed respiratory diseases and disorders. Interestingly, research conducted in Norway showed a similar prevalence of physician-diagnosed asthma in responders and non-responders, while the prevalence of chronic cough and asthma medication use was overestimated [57]. Nevertheless, no analysis of non-responders was possible in this study. Further bias, related to the potential reduction in the number of analyzed observations caused by missing data, was diminished by the use of multiple imputation method in the logistic regression analysis.

It should be noted that the use of indirect methods of the specification of exposure to traffic-related ambient air pollution, like the vicinity of a main road or traffic intensity, to assess the potential adverse health effects, may be useful in documenting the influence of road transport on the children's respiratory tract. A questionnaire addressed to parents may be used to select a group of children for whom the clinical assessment of the respiratory status should be made to unambiguously assess the relationship between traffic and their respiratory health.

CONCLUSIONS

Children living in the vicinity of main roads, or within the area characterized by high traffic flow, have been more frequently diagnosed with asthma or other adverse respiratory tract symptoms. The data presented in this study have not confirmed the statistically significant relation between the studied surrogates of exposure to traffic-related air pollution and spirometry indices, or the prevalence of positive skin prick tests. The vicinity of a main road, as well as traffic intensity, may be useful in assessing the relationship between road transport and potential respiratory health problems among exposed inhabitants.

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