Influence of Traffic-Related Air Pollutants on Lung Function

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Abstract

We investigated the influence of traffic-related air pollutants on respiratory function, with a focus on the non-smoking residents of the capital city of Warsaw in Poland, who lived close to busy streets. The results demonstrate that people living in some parts of the city show symptoms of bronchial obstruction over four times more often than those from the control group consisting of the inhabitants of a remote region in eastern Poland, with considerably less air pollution. Using multiple regression models it was shown that, apart from the place of living, the floor the apartment is situated on, the length of residence, allergy, and physical activity are the factors that significantly influence the forced expiratory volume in 1 s (FEV1) and the pseudo-Tiffenau index (FEV1/FVC).

Keywords

Bronchial obstruction • Health • Municipal environment • Pulmonary function • Traffic congestion • Traffic-related air pollutants

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1 Introduction

Studies on the influence of air pollution on human health conducted in the 1990s (Osterlee et al. 1996; Schwartz 1994; Wjst et al. 1993) point to a close connection between exposure to pollutants and the development of diseases of the respiratory, circulatory, and nervous systems. Air pollution as a factor aggravating the symptoms of chronic obstructive pulmonary disease (COPD) has been known for over 50 years, which contributed to the development of air quality standards. This has resulted in a significant fall in air pollutant emissions from combustion of fossil fuels, especially particulate matter (PM) and sulphur dioxide (Badyda et al. 2013; Klejnowski et al. 2012; Majewski and Przewozniczuk 2009). Dynamic growth of road traffic has, however, caused an increase in the level of other pollutants, such as ozone, nitrogen oxides, or particulate matter of the diameter less than 10 μm (MacNee and Donaldson 2000), especially less than 2.5 μm or even 1.0 μm. Actually, air pollution occurs in the form of a mixture of various types of gases and particular matter, the concentrations of which change depending on the measurement location, emission sources, prevailing directions of air mass movement, climatic, meteorological, and topographic conditions. The most common air pollutants are: particulate matter, tropospheric ozone, nitrogen oxides, sulphur oxides, heavy metals and aromatic hydrocarbons, especially polycyclic ones (Chen and Kan 2008; Samet and Krewski 2007; Brook et al. 2004).

As shown by Martin et al. (2010), the main air quality problem in Europe is high exposure to particulate matter and ozone, to nitrogen oxides in some regions, and to benzo(a)pyrene in case of Poland. An important factor that has a significant contribution to the current situation is road traffic, which in the Polish conditions is gaining special significance. Dynamic growth in the number of vehicles combined with much slower development of the road network, causes a noticeable reduction in average traffic velocity, which is particularly important in large urban areas. Street networks are unable to efficiently handle generated traffic. This results in increasing levels of air pollutants, which may lead to greater incidence of chronic respiratory diseases. As indicated by Keller et al. (1995), motor vehicles moving on congested streets with a low average speed significantly increase fuel consumption (over 20 dm^3 per 100 km) and as a result, emissions of air pollutants like carbon monoxide, nitrogen dioxide, polycyclic aromatic hydrocarbons, and in case of diesel engines also particulate matter.

Human health hazard is primarily conditioned by the size and chemical composition of particulate matter. Particles of the diameter below 10 μm get through the throat and nose to lower parts of the respiratory system. Those smaller than 3 μm are easily deposited in pulmonary alveoli, which may result in serious health hazard. Particles of even smaller diameters may enter to the circulatory system and move to various organs including the brain. Results of studies conducted in Germany by Franck et al. (2011) showed that exposure to solid particles of the aerodynamic diameter of 0.01 μm has an influence on the occurrence of hypertension. Most frequent consequences of long-term exposure to high levels of air pollution include chronic obstructive pulmonary disease and bronchial asthma (Andersen et al. 2011). A cohort study conducted in Denmark (Andersen et al. 2011) on a sample of over 57,000 patients showed that a year-long living close to main roads has statistically significant contribution to the increase of COPD incidence. The study proved that the hazard ratio of COPD amounts to 1.08 with an increase of interquartile range of 35-year-long average concentration of NO_2 by 5.8 $\mu g/m^3$, whereas a closer relationship was observed in patients with diabetes (1.29) and bronchial asthma (1.19). Similar study, on a Swedish example (Lindgren et al. 2009) showed that a 100-m distance of residence from a busy road (traffic intensity of over ten cars per min), in comparison with a road of small traffic intensity, was connected with the incidence of bronchial asthma (OR = 1.40, 95 % CI = 1.04–1.89) and COPD (OR = 1.64, 95 % CI = 1.11–2.4).

Nafstad et al. (2004) demonstrated that long-term exposure to air pollutants in the Norwegian urban environment may lead to increased mortality from respiratory and cardiovascular diseases. The mortality risk factor amounts to 1.16 for respiratory diseases other than cancer, 1.11 for lung cancer, and 1.08 for ischemic coronary disease. A cohort study conducted in Canada on a sample of over 450,000 people (Gan et al. 2010) showed a linear relation between traffic-related air pollution and coronary heart disease. The incidence of heart ischemia was 1.19 times greater among residents of buildings 150m away from a motorway or over 50 m away from a main road, in comparison with people living at longer distances from busy roads. There is also a growing body of evidence that long-term exposure to air pollution is related to an increase in mortality due to cardiovascular diseases (Brunekreef et al. 2009).

An English study (Peacock et al. 2011) showed that also short-term exposure to air pollution (NO_2, O_3, SO_2, or PM_{10}) contributes to aggravation of COPD symptoms. Traveling during the rush hours, with greater vehicle traffic, and consequently with higher air pollution, may have adverse health effects. A Dutch study (Zuurbier et al. 2011) showed that even short-term exposure to high levels of particulate matter results in a decrease in respiratory system immunity and risk of inflammation. Daily exposure to high levels of pollution contributes to the occurrence of ischemic heart disease, heart failure and cardiac arrhythmia, peripheral arterial disease, and even increased risk of sudden death (Nelin et al. 2012; Autrup 2010).

In the present study we investigated the influence of traffic-related air pollutants on respiratory function, with a focus on the non-smoking residents of the capital city of Warsaw in Poland, who lived close to busy streets.

2 Methods

2.1 Subjects

The study was approved by a local Ethics Committee of the Military Institute of Medicine in Warsaw, Poland, and informed consent was obtained from all study participants.

Pulmonary function tests were conducted systematically from April to June and from September to October in the years 2008–2011. Selection of the study period was conditioned by the necessity of avoiding potential influence of short-term effects of air pollutants from sources other than traffic, e.g., municipal and domestic sources, and holiday periods, which could affect representativeness of the sample.

The analysis encompassed 4,725 results of pulmonary function tests. In Warsaw, 3,834 people living in the vicinity of 7 selected busy roads were tested, including 1,608 women and 2,226 men aged 9–91 (mean age 51 ± 20 years). The proportion of non-smokers was 50.5 % (1,938 people). The control group consisted of 891 individuals living in rural areas isolated from direct impact of traffic-related air pollutants emission. The group included 471 women and 420 men aged 9–91 (mean age 50 ± 20). 50.4 % of the group (449 people) were smokers. The results of the tests from patients presently treated for chronic obstructive pulmonary disease (COPD) or bronchial asthma, as well as those who did not cooperate with the examiner were excluded from further analysis.

2.2 Protocol

The examination was conducted according to the following scheme:

- information about the aim of the examination and the lack of its harmful impact on the human body;
- subjective research – a questionnaire including: information on place of residence (locality, floor, distance to main roads, period of residence, etc.) and its conditions (heating method, gas cookers, other air pollutants emitters), smoking habit and its intensity, passive smoking, exposure to harmful factors in workplace and living place, current pulmonary diseases, presence of respiratory disease symptoms, allergies and anthropometric data;
- objective research – pulmonary function test carried out in the sitting position (Easy One spirometers; AeroMedika, Warsaw, Poland) after a few-minute time given to adapt to the

new breathing conditions. Several flow-volume curves were recorded, until repeatability in accordance with the American Thoracic Society (ATS) criteria was achieved. The test results included following parameters:

- FVC (forced vital capacity);
- FEV_1 (forced expiratory volume during the first second of expiration);
- FEF_{50} (forced expiratory flow at 50 % of FVC);
- FEV_1/FVC (the so-called pseudo-Tiffeneau factor);
- PEF (peak expiratory flow).

According to the ATS and the Polish Respiratory Society guidelines, research was carried out until at least three repeatable results were obtained, i.e., results for which the values of indicators for particular measurements did not vary by more than 5 %. Predicted values were calculated according to commonly used ERS/ECCS standards (Quanjer et al. 1993).

The Shapiro-Wilk test was used to assess normality of data distribution. Data were compared using both parametric, ANOVA, and non-parametric, Kruskal-Wallis, tests as required. A $p < 0.05$ was accepted as a statistically significant level. Multiple regression models were used to assess factors determining variability of spirometric indices. Statistical analysis was conducted using Statistica 9.1 software.

3 Results and Discussion

Presentation of the results is limited to the non-smoking persons only in order not to confuse cigarette and traffic-related air pollutants. The non-smoking group included 2,387 inhabitants, including 809 women and 1,578 men, aged 9–91 (mean age 54 ± 21 years), comprising 1,938 Warsaw residents and 449 rural areas inhabitants. Both city and rural areas inhabitants had spirometric indices within the accepted norms. However, there were significant differences between the two groups. The mean values of FEV_1, FEF_{50}, and the FEV_1/FVC ratio were lower in the city residents ($p < 0.05$). Moreover, significant differences were also noted in case of PEF. Overall, the results indicate the adverse effects on lung function of living in a big city compared with rural areas, excluding the potential confounder of cigarette smoking (Table 33.1).

We also calculated the percentages of people with symptoms of bronchial obstruction. The symptoms were broken down by the degree of obstruction severity, where bronchial obstruction was diagnosed when the FEV_1/FVC values were below 70 %, and mild obstruction was assumed for $FEV_1 \geq 80$ %, moderate for FEV_1 50–79 %, and severe for $FEV_1 \leq 50$ %predicted (Table 33.2). In all categories of obstruction above outlined the percentage of afflicted individuals was several-fold higher in Warsaw City than rural areas inhabitants.

To sum it up, the results of this study demonstrate the following:

- decreases in the essential spirometric indices regarding the assessment of bronchial patency in the big city residents compared with the inhabitants of rural areas with no appreciable traffic-related air pollution;
- 4.1-times more people with bronchial obstruction among the Warsaw residents compared with those living in rural areas;

Table 33.1 Spirometric indices in non-smoking inhabitants of Warsaw and rural areas

Spirometric variable	Warsaw group	Rural area group
FEV_1	95.3 ± 19.3**	100.3 ± 17.2
FVC	107.5 ± 24.9	108.1 ± 18.9
PEF	96.2 ± 24.2*	100.5 ± 22.8
FEF_{50}	75.0 ± 32.8**	86.0 ± 31.3
FEV_1/FVC	94.5 ± 14.4**	98.6 ± 10.6

Data are mean %predicted values ± SD

*$p < 0.05$; **$p < 0.001$ for the differences between the two groups (Kruskal-Wallis test)

Table 33.2 Percentages of non-smokers with airflow obstruction in urban and rural areas groups

Obstruction severity	Warsaw group	Control group
Mild	3.1	1.1
Moderate	4.4	0.7
Severe	1.7	0.5
All	9.1	2.2

- rather a moderate degree of bronchial obstruction among the city residents, with the FEV_1 level in a 50–79 % predicted range. This level of obstruction was found in the present study in the non-smoking individuals residing in a big city with traffic-related air pollution. A similar level of obstruction is routinely found in smokers suffering from COPD, and the existence of obstruction is not often appreciated in people exposed mainly to environmental factors.

The etiology of chronic pulmonary diseases includes mainly smoking and air pollution. Therefore, it may be assumed that among non-smokers, low values of sensitive lung function variables and over a four-times higher percentage of people with obstruction in the group of city inhabitants living close to streets with heavy traffic, as opposed to those living in unpolluted rural areas, could be a result of exposure to excessive concentrations of pollutants. We further performed the assessment of factors which could influence spirometric variables using multiple regression models. For this purpose, the relationship described in Eq. 33.1 below was used:

$$\hat{Y} = b_0 + b_1X_1 + b_2X_2 + \ldots + b_kX_k \qquad (33.1)$$

where:

$\hat{Y}$ – predicted value of the dependent variable Y;
$X_1, X_2, \ldots, X_k$ – independent variables;
$b_1, b_2, \ldots, b_k$ – regression coefficients

Regression coefficients were estimated using the maximum likelihood method. Separate models for FEV_1 and FEV_1/FVC were created. The models contain only the independent variables that significantly ($p < 0.05$) influence the variability of dependent variables. The models for FEV_1 and FEV_1/FVC are given in Eqs. 33.2 and 33.3, respectively:

$$\begin{aligned} FEV_1\% = & 108.795 - 6.942 \cdot LIV \\ & - 0.092 \cdot TLV + 0.329 \cdot FLR \\ & - 3.198 \cdot ALL + 3.974 \cdot SPR \\ & - 0.088 \cdot AGE - 2.086 \cdot GEN \end{aligned} \qquad (33.2)$$

$$\begin{aligned} \frac{FEV_1}{FVC\%} = & 103.701 - 4.729 \cdot LIV \\ & + 0.323 \cdot FLR + 1.289 \cdot SPR \\ & - 0.110 \cdot AGE \end{aligned} \qquad (33.3)$$

where:

LIV–place of living – dichotomous variable; rural area inhabitants (LIV = 0), urban area inhabitants (LIV = 1); TLV–period of living (years); FLR–floor of residence (0,1,. . .,n); ALL–allergies – dichotomous variable; no allergies (ALL = 0), presence of allergies (ALL = 1); SPR–sports activities – dichotomous variable; no physical activity (SPR = 0), presence of physical activity (SPR = 1); AGE–age of investigated person (years); and GEN–gender – dichotomous variable; man (GEN = 0), woman (GEN = 1).

The elaboration of the models demonstrates that the predicted values of both FEV_1 and FEV_1/FVC decline:

- among city inhabitants;
- with increasing period of living in a particular place, which is partially related with age;
- with decreasing floor of residence;
- with the presence of allergy;
- among sedentary people not practicing physical activity;
- with increasing age of a person;
- in female gender.

The decline appeared statistically more expressed for FEV_1 than that for FEV_1/FVC.

4 Conclusions

Among the non-smoking people living in the vicinity of busy roads in a large city, symptoms of bronchial obstruction are over four times more frequent than in rural areas inhabitants. The essential spirometric variables FEV_1, FEV_1/FVC, and FEF_{50} were appreciably lower in the city than rural inhabitants. This points to an increased percentage of people who exhibit inflammatory reactions in the respiratory system due to exposure to air pollution. The observation was confirmed by the results of multiple regression models pointing to the number of factors that worsen the spirometric variables, particularly in the city inhabitants. The lower floor of residence in buildings, the extended time of living close to busy streets, advancing age, lack of physical activity, and allergy all have a negative influence on lung function. Thus, heavy traffic-related air pollution is an essential factor impairing health in big cities.

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Conflicts of Interest The authors declare no conflicts of interest in relation to this article.

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