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Risk of bronchi obstruction among non-smokers—Review of environmental factors affecting bronchoconstriction☆

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ABSTRACT

In order to find relationship between exposure to traffic and traffic-related air pollutants, pulmonary function tests and a detailed questionnaire were conducted among 3997 selected inhabitants of Warsaw (Poland) and 988 residents of rural areas. Advanced statistical analyses (including GRM models, correspondence analysis and parametrical tests) have been completed.

Statistically significant differences between average percentages of predicted values of pulmonary function parameters were found. Among urban area inhabitants the values of FEV_1, MEF_{50} and FEV_1/FVC were statistically significant ($p < 0.05$) lower compared with the residents of rural areas (in the non-smoking group this differences were strong ($p < 0.001$)). General linear regression models indicated that residence in the vicinity of urban busy roads fosters a decrease of spirometric parameters. Physical activity however has a positive effect on pulmonary function (exemplified by FEV_1) and allows to reduce part of the negative health effects of traffic-related emissions.

The results of the presented study demonstrate that long-term residence under the influence of heavy traffic and high concentrations of traffic-related air pollutants reduces respiratory function parameters, which may result in increased bronchial hyperresponsiveness.

1. Introduction

According to the World Health Organization (WHO), air pollution is currently a major environmental risk factor to human health. Therefore substantial burden of chronic and acute respiratory diseases (including asthma and COPD) is caused by high air pollutants concentrations (Balmes, 2009; World Health Organization, 2014a). It has been estimated that the number of premature deaths attributable to outdoor air pollution in cities reached 1.34 million worldwide (World Health Organization, 2008). When the rural population is taking into account, the number of premature deaths due to ambient air pollution reaches the level of 3.7 million (World Health Organization, 2014b). The exposure to particulate matter only is responsible, according to the WHO estimates, for approximately 8% of deaths from lung cancer, 5% due to cardiovascular diseases and 3% due to respiratory infections (World Health Organization, 2009). It should be highlighted that the International Agency for Research on Cancer (IARC) classified outdoor air pollution (and separately particulate matter) as carcinogenic to mankind (World Health Organization, 2013). It is pointed out that already the prenatal exposure to air pollution may cause higher infant mortality which is associated with direct toxicity of particles due to their translocation across tissue barriers or penetration through the cellular membranes (Proietti et al., 2013). The results of the ESCALA project (a multicity study carried out in Latin America), demonstrate that the increased risk of mortality is associated with PM_{10} (particles with aerodynamic diameter not greater than 10 μm) or O_3 concentrations (Romieu et al., 2012). PM_{10} was associated with increased mortality from COPD and other respiratory, cardiopulmonary, cardiovascular, and cerebrovascular diseases in most of

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the analyzed cities. Increases in mortality associated with the ambient O_3 were lower than those related to PM_{10}. Increased mortality from respiratory causes and lower tract respiratory infections due to increased PM_{10} concentrations were also observed in infants and children.

In the European Union the largest share of emission of major air pollutants comes from the commercial and household sector, transport, energy production and distribution and industrial sector. The highest concentrations of air pollutants such as PM, CO, NO_2 or PAHs (polycyclic aromatic hydrocarbons) are recorded in the areas located in the immediate vicinity of heavily congested urban roads and those characterized by the intensive use of individual ovens/furnaces for thermal energy production (especially from coal and/or wood combustion). In these locations, the population exposure to adverse health effects is particularly significant (Kozielska et al., 2013; Rogula-Kozłowska et al., 2013; Majewski et al., 2013).

The results of a cohort study conducted in Denmark with a sample of over 57,000 patients, presented by Andersen et al. (2011), have shown that a year-long habitation period close to main roads, as a source of air pollution, has a significant contribution to the increase in the COPD incidence. The studies showed that the hazard ratio of COPD equals 1.08 with the increase of the interquartile range of a 35-year-long average concentration of NO_2 by 5.8 $\mu g/m^3$. Similar results can be observed in a Swedish example (Lindgren et al., 2009). A 100-meter distance of a residence from a busy road (traffic intensity of over 10 cars per minute), compared with a road of small traffic intensity, was linked to the incidence of the following diseases: bronchial asthma (OR = 1.40, 95% CI = 1.04–1.89) and COPD (OR = 1.64, 95% CI = 1.11–2.4). Even a short-term exposure to air pollution (NO_2, O_3, SO_2 or PM_{10}) aggravates COPD symptoms (Peacock et al., 2011). Travelling during rush hours, with higher concentrations of air pollution, may have adverse health effects. Observations made by Dutch researchers (Zuurbier et al., 2011) indicated that a short-term exposure to a high ambient air concentration of PM results in reduced pulmonary function, respiratory tract immunity, and increased risk of inflammation. Exposure to urban traffic-related PM also significantly increases cytotoxicity, oxidative stress, and pro-inflammatory responses of lung epithelial cells and macrophages compared with PM from rural areas (Michael et al., 2013).

As Sunyer (2009) stated “lung function is an excellent operative marker of the effects of air pollution in the general population”. The research presented in this article was based exactly on the determination of the impact of air pollutants related to the vehicle traffic on pulmonary function of people living in the vicinity of urban roads characterized by the average traffic density between 28,000 and 74,000 cars a day.

2. Methodology

2.1. Material

Research encompassed 4985 people living in the vicinity of seven selected busy roads in Warsaw (Poland) and in rural areas isolated from the direct impact of air pollutant emissions, including traffic-related emissions (control group). Pulmonary function tests were conducted systematically from April to June and from September to October 2008–2011, to avoid potential influence of short-term effects of air pollutants from sources other than traffic (especially municipal and domestic sources) and holiday periods, which could affect representativeness of the sample.

In the cross sections of streets, traffic parameters (traffic density, structure, and speed) and concentrations of air pollutants (CO, NO_2, PM_{10}) were measured. To compare the long-term exposure of the urban and control groups on air pollution, the measurement results from the Air Quality Monitoring System in Warsaw (3 stations) and rural areas (two stations) were used. A 5-year mean concentration of PM_{10} from the study period (2008–2012) was taken into account.

The results of the tests from patients treated at the time for chronic obstructive pulmonary disease (COPD) or bronchial asthma, and those who did not cooperate with the doctor during the examination, were excluded from further analysis.

The final analysis encompassed 4725 tests of pulmonary function. In Warsaw, 3834 examinations were performed, including 1608 women and 2226 men aged 9 to 91 (mean 50.9 ± 19.7 years). The proportion of non-smokers was 50.5% (1938 people). The control group consisted of 891 individuals, including 471 women and 420 men aged 9 to 91 (mean 50.1 ± 19.1 years). 50.4% of the group (449 people) were non-smokers. The presentation of the results was limited to non-smoking people only, due to the general aim of this study, which was the assessment of the influence of traffic-related air pollution on spirometric parameters.

2.2. Methods

The examination consisted of: information on the aim of the pulmonary function test and lack of its adverse effects on human health, subjective research (questionnaire) and objective research (pulmonary function test). The pulmonary function test included following parameters:

- FVC (forced vital capacity)—this is the capacity of air, which is exhaled by a tested person during a forced exhalation after maximum slow inhalation;
- FEV_1 (forced expiratory volume during the first second of expiration)—this is the capacity of air, which is exhaled by a tested person within the first second of expiration;
- FEF_{50} (forced expiratory flow at 50% of FVC)—this is the velocity of air flow in the middle phase of exhalation;
- FEV_1/FVC (the so-called pseudo-Tiffeneau factor)—this is the percentage indicator of FEV_1 capacity, in its relation to the present forced vital capacity;
- PEF (peak expiratory flow)—this is the maximum velocity of flow measured during forced exhalation.

Details of the examination were described by Badyda et al. (2013).

Taking into account the 5-year mean PM_{10} concentrations from urban and rural areas and pulmonary function results we calculated the difference in FEV_1 (as the most important parameter indicating the occurrence of obstruction) between two examined groups exposed to different levels of air pollution.

The statistical models were the ultimate confirmation of preliminary dependences and mutual relationships. We used the analysis of variance (ANOVA) with one-way classification and a generalized regression model (GRM) path. However, it is worth noting that ANOVA, being at most a two-dimensional model, is treated as complementary to generalized regression model. GRM is strictly speaking not a model, but an authentication pathway which enables conducting step-wise regression comprehensively. It allows using general, linear model methods which enable building models for the systems containing effects with many degrees of freedom for qualitative predictors, and for the systems containing effects with a single degree of freedom for continuous predictors. Therefore, GRM enables a precise identification of the factors in the frequency domain, including interactions between factors in nominal and ordinal measurement scales from a multidimensional perspective. It was assumed, that this model may ultimately confirm the occurrence of the dependence between FEV_1 and exogenous factors.