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Effects of Air Pollution on Growth in Schoolchildren

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A B S T R A C T

The growth is considered a very sensitive indicator of the impact of environment of the health status of children. The aim of the study was to investigate whether air pollution is related to children's growth. The subjects were 1059 pupils, aged 7–11 years, living for more than ten years in the same home in the city of Niš (Serbia). Exposed group of children (N=545) were attending the school located in a city area with a high level of air pollution, while the children (N=514), in the comparison group, designed as non-exposed group, were attending the school in the area with a lower level of air pollution. The air concentrations of black smoke, nitrogen dioxide, sulfur dioxide and lead in sediment matter were determined in ten-year period. Air pollution is associated with children's height and weight, specially before the age of 9 years. There was a significant difference in the prevalence of thinness in children exposed to higher concentrations of air pollutants (p=0.038). It might be possible that air pollution negatively contributed to the growth rate in urban children.

***Key words**: air pollution, children, growth, pattern*

Introduction

Various epidemiological studies indicate that exposure to elevated levels of different ambient air pollutants is associated with either acute or chronic health effects in children[1–3]. Less is known about the association between air pollution exposure and the continuing process of growth and development, that one of the most important characteristics in childhood. Some studies suggest that air pollution is associated with impaired growth in utero measured by birth weight[4], intra uterine growth retardation[5] and preterm birth[6].

Several epidemiological studies on population group, considered to be very susceptible to the effect of air pollution, were performed in Niš, Serbia[7–12]. The prevalence of respiratory symptoms and illnesses, anemia, skin symptoms, allergy and cancer were monitored. The effects of ambient air pollution on children's health are well documented in these studies and it was determined that even relatively low levels of air pollution are harmful. However, there were only few attempts to examine the influence of air pollution on the growth and development of children, mostly under other research, so it was our main motivation to get into one research in this area.

The aim of the study was to investigate the impact of air pollution on children's growth.

Subjects and Methods

The study sample consisted of children aged 7 to 10 years, citizens of Niš (Serbia). The group of exposed children, attended school in a city area with a high level of outdoor air pollution (School 1), while the children of the comparative group, designated as the non-exposed group, attended school in an area with a lower level of outdoor air pollution (School 2). School 1 is located in an urban area with major traffic roads surrounding the school building and School 2 in a residential area, far from the main street. All children lived in the areas close to the schools and at a distance of 0.5 km from the measuring site. The exclusion criteria were any acute or chronic ill-

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nesses and residence within the studied area for less than 10 years prior to the study.

Parents were informed about the aims and performance of the study. The parents agreed with involvement of their children in the study and were requested to fill in an original structured questionnaire. Data regarding demographic characteristics, parents' smoking habits, parents' education level, density of habitation (number of people living in one room), mold presentation in home and mode of heating were collected. After completing the questionnaire, parents' height and weight were measured.

In each school, the trained nurses performed anthropometric measurements using a standardized procedure[13]. The procedure was approved by the Regional School Authorities of Niš (Serbian Ministry of Education). For measuring body height Martin's altimeter was used, with the accuracy of 0.1 cm and for measuring body weight – electronic scale (with a precision of 100 g). On the basis of obtained measures the body mass index (BMI) was calculated as weight in kg divided by square of height in m^2[13,14]. Weight status was defined according to age and sex specific BMI cut-off points and thinness were defined by the 5th percentile. Birth weight and birth height was taken from hospital records. The investigation was done in 2005.

Exclusion criteria were any acute or chronic illnesses and residence within the study area loess then 10 years prior to the study.

The concentrations of black smoke (BS), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and lead (Pb) in sediment matter were determined in 24-h samples of air collected from January 1995 to December 2004. Sampling equipment was placed at 1.5 m above floor level at two sampling sites near the school buildings.

The ambient level of black smoke concentrations was measured by reflection. Sampling was performed by X⁻s of a pump operating with a flow rate of 1 L/min through Whattman N°1 paper filters. At the same time, the air concentration of sulfur dioxide was measured by bubbling a certain volume of air through a solution of potassium tetrachloromercurate[15]. The sulfur dioxide in the air stream reacted with the solution to form a stable monochlorosulfonatomercurate complex. During the subsequent analysis, this complex was brought into reaction with acid-bleached pararosaniline dye and formaldehyde yielding intensely colored pararosaniline methyl sulfonic acid. The optical density of this species was determined spectrophotometrically at 548 nm and was directly related to the amount of sulfur dioxide collected. The total volume of the air sample was determined from the flow rate and the sampling time. The concentration of sulfur dioxide in the ambient air was calculated and expressed in mg/m^3. The lowest limit of detection was 1.7 $\mu g/m^3$.

Ambient nitrogen dioxide was collected with a pump containing triethanolamine in its tube with the exact amount of the reacted nitrogen dioxide using the standard spectrophotometry[16]. The minimum detectable limit of the method had been determined to be 2.0 $\mu g/m^3$.

Lead in sediment matter was collected with absorbed solution of sulfur acid and was detected by graphic furnace atomic absorption spectrometry[17]. The lowest limit of detection was 0.5 $\mu g/m^3$.

Indoor air quality was determinated by three variables: environmental tobacco smoke (ETS), system of home heating and presence of dampness or mold stains on the apartment walls. ETS was expressed as the presence of at least one regular smoker at child's home.

A statistical package SPSS 10.0 was used for data analysis. Descriptive statistics was computed for all variables. Mantel-Haenszel chi-square test was used to compare frequencies of categorical variables between two groups. Student's t test was used to compare values of non-categorical variables. Statistical significance was set at an a level of 0.05.

Results

Analyses were performed in 1059 children from the two elementary schools. Of the final study sample, 545 children (51.46%) lived in the more polluted area of the Niš city and 514 (48.54%) in the less polluted area. Distribution of the study population by gender and age is reported in Table 1.

Table 2 shows the descriptive statistics for examined children. The children from the high air pollution area of the city had better educated parents, lived more often in houses with mold stains on the walls and higher density of habitation. Also, children from the lower air pollution area showed higher birth weight than children from high-pollution area..

TABLE 1
DISTRIBUTION OF THE CHILDREN BY GENDER AND AGE*

Characteristics of children	Total N=1059	Exposed N=545	Non-exposed N=514
Male/Female*, N	520/539	289/256	231/283
7 yr, n	209	110	99
8 yr, n	207	104	103
9 yr, n	273	141	132
10 yr, n	370	190	180

* $p<0.05$

TABLE 2
CHARACTERISTICS OF EXAMINED SCHOOLCHILDREN

Characteristics	Exposed N=545	Non-exposed N=514	p
Age of children, in years ($\overline{X}$±SD)	8.96±1.54	8.78±1.56	0.059
Birth weight, g ($\overline{X}$±SD)	3321.93±401.23	3489.54±438.52	<0.001
Birth height, cm ($\overline{X}$±SD)	52.88±2.13	52.81±2.11	0.589
Mother's height ($\overline{X}$±SD)	67.12±11.94	66.37±10.31	0.276
Father's height ($\overline{X}$±SD)	89.53±12.75	88.22±12.16	0.088
Parents with higher education	82 (15.05%)	16 (3.11%)	<0.001
Mother smoked during pregnancy	93 (17.06%)	83 (16.15%)	0.689
Exposure to ETS	234 (42.93%)	231 (44.94%)	0.511
Density of habitation (person/room) (X±SD)	0.82±0.32	0.88±0.29	0.002
Central heating in the household	106 (19.45%)	103 (20.04%)	0.810
Mold stains on the apartments walls	53 (9.72%)	32 (6.23%)	0.036

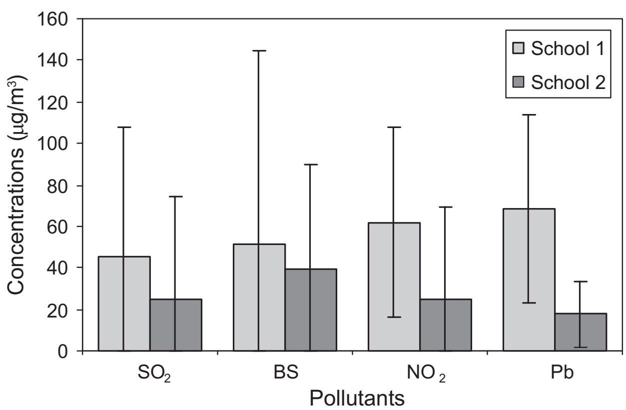

Fig. 1. Levels of air pollution studied during the investigated 10-year period.

The results of air pollution measurements are summarized in Figure 1. All concentrations of the air pollutants measured during the period 1995–2004 at the location in School 1 were higher when compared to the concentrations of the same pollutants measured at the location in School 2. This differences between average annual values for all the air pollutants between two measuring sites were statistically significant for the level $p<0.01$.

Results shown (Table 3–5) that body weight, body height and BMI were heterogeneous over the age groups. Air pollution was associated with children's height and weight at 7 and 8 years. After that age the association had disappeared by the age of 9 and 10.

In the Table 6 was shown the prevalence of thinness among the examined children. There was a significant difference in the frequency of thinness in children exposed to higher concentrations of air pollution when compared to those who were exposed to lower concentrations of air pollution ($\chi^2=4.32$, $p=0.038$).

Discussion of results

This investigation suggest that a child's growth is related to postnatal exposure to higher air pollution in the residence area at 7 and 8 years of age.

Similar results were obtained in other studies that investigated impact of the air quality on the children's growth[18–23]. Bobak et al. found that children's height was inversely associated with air pollution between the ages of 2 and 7 years and after the age of 7 years the association became weaker and had disappeared by the age of 15[18]. The previous study conducted in Poland found that the growth rate of children at 9 years of age living in a highly polluted area was 1.5 cm lower than in a control area[24].

It is difficult to determine whether one of the measured pollutants, alone or in combinations, was responsible for the observed effects in children. However, it might

TABLE 3
DIFFERENCES IN CHILDREN'S BODY HEIGHT

Age of children, in years	Boys		p	Girls		p
	Exposed	Non-exposed		Exposed	Non-exposed	
7	124.56±6.50	128.36±7.60	<0.001	123.77±6.56	126.83±7.43	<0.001
8	131.07±6.47	135.59±9.11	<0.001	130.59±6.37	137.91±6.09	<0.001
9	137.98±7.07	137.97±6.67	0.982	137.51±6.99	136.98±6.54	0.201
10	140.57±6.70	140.42±6.99	0.722	139.66±7.04	140.45±6.68	0.062

TABLE 4
DIFFERENCES IN CHILDREN'S BODY WEIGHT

Age of children, in years	Boys		p	Girls		p
	Exposed	Non-exposed		Exposed	Non-exposed	
7	25.18±5.52	26.48±5.39	0.006	24.13±5.14	26.03±6.13	<0.001
8	28.27±6.42	31.65±8.94	<0.001	27.39±6.08	35.55±6.80	<0.001
9	32.94±7.49	32.39±7.47	0.396	32.24±7.19	31.72±6.97	0.401
10	36.16±9.06	34.78±7.52	0.058	34.79±8.28	34.05±8.70	0.318

TABLE 5
DIFFERENCES IN CHILDREN'S BODY MASS INDEX

Age of children, in years	Boys		p	Girls		p
	Exposed	Non-exposed		Exposed	Non-exposed	
7	15.80±2.15	16.21±2.65	0.051	15.67±2.21	16.03±2.78	0.099
8	16.89±2.19	16.33±2.69	0.009	15.94±2.59	16.68±3.08	0.003
9	17.16±2.97	17.18±2.96	0.936	16.79±2.75	16.94±2.91	0.542
10	17.51±2.74	18.13±3.40	0.021	17.10±3.10	17.69±3.02	0.027

TABLE 6
PREVALENCE OF THINNESS IN CHILDREN AND OUTDOOR AIR POLLUTION EXPOSITION

Children	Thinness		Normal		χ^2	p
	N	%	n	%		
Exposed	18	3.30	527	96.70		
Non-exposed	7	1.36	507	98.64	4.32	0.038
Total	25	2.42	1034	100.00		

will be possible that conditions connected with the air pollution and its consequences slow down the growth pattern of children – increased prevalence of respiratory and allergic diseases, longer stay at home, type of house heating, different dietary habits with deficient levels of some nutrients that could affect children's growth, less frequent social contacts, etc.

It is, also, less clear which pollutants are most responsible for changes in growth status of children. Little is known about the possible adverse effects of exposure to complex mixtures of chemicals.

The biological mechanisms linking children's growth with air pollution are not evident, and it also, remains to be confirmed whether the relationship is genuine and causal. A possible mechanism of the adverse effect of air pollutants on the growth rate of children may result from the induction of apoptosis following DNA damage by chemical air pollutants. Another possible mechanism may be related to the occurrence of respiratory diseases and slower lung function growth to children experiencing a long-term exposure to urban pollutants[21–23]. Further study is needed to disentangle this interaction and the underlying mechanisms. Moreover, other factors (genetic disposition, nutrition habits, etc.) contributed to the detected nutritional status of children[25].

Taking into account that there are cities in Serbia with measured air pollutant levels higher than in Niš, it would be useful to conduct epidemiological studies in these cities, too.

This is the first study to describe the relationship between air pollution levels and children's growth among Serbian children in peer/reviewed literature. The results of the study were limited by the short period of the examination and the relatively small number of observed subjects. We hope that our already started examinations with larger sample of children will result in more precise evidence.

In conclusion, it can be summarized that even relatively low levels of air pollution could have a negative impact on children's growth and are hazards to their health. Obviously, further research is necessary to confirm our results.

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UTJECAJ ONEČIŠĆENJA ZRAKA NA RAST ŠKOLSKE DJECE

SAŽETAK

Rast se smatra vrlo osjetljivim pokazateljem utjecaja okoliša na zdravstveno stanje djece. Cilj istraživanja bio je ispitati da li onečišćenje zraka utječe na rast djece. Ispitano je 1059 učenika, u dobi od 7–11 godina, koji žive više od deset godina na istoj adresi u gradu Nišu (Srbija). Izložena skupina djece (N=545) je pohađala školu koja se nalazi u gradskom području s visokom razinom onečišćenja zraka, dok su djeca (N=514), u usporednoj skupini pohađala školu u području s nižom razinom onečišćenja zraka. Zračne koncentracije čađe, dušikovog dioksida, sumpornog dioksida i olova u sedimentu određivani su u desetogodišnjem razdoblju. Onečišćenje zraka je povezano s visinom i težinom djece, posebno prije dobi od 9 godina. Postojala je značajna razlika u učestalosti pothranjenosti kod djece izložene većim koncentracijama onečišćujućih tvari u zraku (p=0,038). Moguće je kako je zagađenje zraka negativno doprinijelo stopi rasta kod urbane djece.