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Original Research

Opposite Trends of Allergic Disorders and Respiratory Symptoms in Children over a Period of Large-Scale Ambient Air Pollution Decline

Grzegorz M. Brożek*, Jan E. Zejda, Małgorzata Kowalska, Mateusz Gębuś, Krzysztof Kępa, Michał Igielski

Department of Epidemiology, Faculty of Medicine, Medical University of Silesia,
Medyków 18, 40-752 Katowice, Poland

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Abstract

The aim of our study was to analyze a 15-year trend in the prevalence of allergic disorders and respiratory symptoms in children living in an urban area of Upper Silesia, Poland. Three cross-sectional studies (1993, 2002, and 2007) in children aged 7-10 showed a statistically significant increase in the prevalence of all physician-diagnosed allergic disorders (1993-2002-2007): asthma (3.4%-4.7%-8.5%); allergic rhinitis (9.1%-13.7%-17.4%); atopic dermatitis (3.6%-8.4%-8.9%); allergic conjunctivitis (4.3%-11.8%-14.9%); allergy to pollen (5.9%-12.3%-17.3%); allergy to food (5.5%-11.0%-17.0%). A simultaneous decreasing trend in the prevalence of coughing correlated with significant improvement of ambient air quality. However, the rising trends could result from both increasing incidence and improved diagnosis of allergic diseases.

Keywords: allergic diseases, respiratory symptoms, children, environmental epidemiology

Introduction

The results of the International Study of Asthma and Allergies in Childhood (ISAAC) revealed an increase in the prevalence of childhood asthma and asthma-like symptoms, as well as other allergic diseases in Eastern Europe, over the years 1994/95-2001/02 [1-3]. In Poland, the prevalence of physician-diagnosed asthma in children aged 6-7 years increased between 1994/95 and 2001/02 from 4.0% to 5.8% in Kraków, and from 1.3% to 5.9% in Poznań [4, 5]. It remains unclear if and to what extent the increase in the occurrence of allergic disorders reflects a measurement error ("greater awareness," "diagnostic shift"), but such an explanation could be supported by little change in the overall prevalence of asthmatic symptoms vis-à-vis a rising trend of diagnosed asthma, as concluded in a comprehensive review of ISAAC's results [1]. In order to address this interpretation, we explored the results of our three respiratory health surveys (cross-sectional studies) performed within a children's respiratory health program initiated at the beginning of the 1990s in the Upper Silesian Industrial Zone, Poland [6, 7]. Our general objective was to examine time trends in the prevalence of allergic disorders and respiratory symptoms in early school children, over a period that is distinctive for a large decrease in ambient air pollution.

*e-mail: brozekg@poczta.onet.pl

Experimental Procedures

Study Location

All three rounds of children's respiratory health survey were performed in the town of Chorzów (1993 population: 130,000; 2007 population: 114,000), located in the central part of the Upper Silesian Industrial Zone (USIZ), the most industrialized area of Poland (Katowice district). For decades its mining, metallurgical, and chemical industries have been the major sources of environmental pollution. At the end of the 20th century the emission of dusts generated in USIZ made up 22% of national emissions, and the emission of gases made up 28% of national emissions. Chorzów is an old industrial centre long known for its coal mining and metallurgical industry that was extensive until the end of the 20th century. Over a recent socio-economic transition (since 1990) the industrial activity in the town has substantially declined – coal mines and a number of metallurgical plants are no longer in operation. These changes, as well as the endorsement of air pollution control measures, have resulted in an apparent improvement in ambient air quality. Based on the records available from the regional environmental protection agency, average annual area concentrations of particulate matter (PM_{10}) were 154 μg/m^3 in 1993 and 49 μg/m^3 in 2007; of sulphur dioxide (SO_2) were 82 μg/m^3, in 1990 and 14 μg/m^3 in 2007; and average annual area concentrations of nitrogen dioxide (NO_2) were 100 μg/m^3 in 1990 and 46 μg/m^3 in 2007 [8].

Study Subjects

The subjects were children aged 7-10 years attending primary schools. In 1993 there were 4,598 candidate children in 28 schools, in 2002 there were 4,870 candidate children in 16 schools, and in 2007 there were 4,195 candidate children in 17 schools. Using a cluster sampling with a primary school as a sample unit we selected 1,579 children in 9 schools in 1993, 1,821 children in 5 schools in 2002, and 2,005 children in 7 schools in 2007. Parents or guardians of selected children were asked to fill in questionnaires. Each questionnaire was accompanied by a letter explaining the study objectives and an informed written consent form. The same questionnaire was used in all three rounds of the survey and the response rates were 72% in 1993, 82% in 2002, and 83% in 2007. All three surveys were performed in one town, using the same study protocol and under the supervision of one principal investigator. All surveyed groups were similar in terms of gender and age structure (Table 1). No significant in- or out-migration involving children was present during the study period in the town of Chorzów [9].

Allergic disorders and respiratory symptoms were ascertained according to the answers to questions taken from the Polish language version of a validated children's questionnaire of respiratory symptoms used in the Central European Study of Air Pollution and Respiratory Health (CESAR) [6, 10]. The list of allergic disorders included asthma, obstructive bronchitis, allergic rhinitis, allergic conjunctivitis, atopic dermatitis, pollen-, dust- and food-allergy – the diagnoses made by physicians ever in the past. Chest wheezing (ever) was defined according to the answer to the question: "Has the child ever had wheezing or whistling in the chest at any time in the past?", and current chest wheezing was defined according to the answer to the question: "Has the child's chest sounded wheezy or whistling in the last 12 months?" Attacks of dyspnea (ever) were defined according to the answer to the question "Has the child ever had attacks of dyspnea?", and current dyspnea attacks according to the answer to the question "Has the child had attacks of dyspnea during the last 12 months?" Dry cough during the night was defined according to the answer to the question "Has the child had a dry cough at night in the last 12 months, apart from coughing with a cold or chest infection?" Morning cough was defined according to the answer "Does the child usually cough in the morning in autumn/winter?", and chronic cough was defined according to the answer to the question "Did the child cough on most days for at least 3 months consecutively last autumn/winter?" Asthma and other diagnoses of allergic diseases/disorders were defined according to the answer to the question "Has the child ever had a given disease diagnosed by a physician?"

Table 1. Characteristic of children participating in the three cross-sectional studies (1993-2002-2007).

	Year 1993 n=1,137	Year 2002 n=1,487	Year 2007 n=1,661	p
Girls [%]	50.6	49.5	51.6	0.5*
Boys [%]	49.4	50.5	48.4	
Age [Mean±SD]	8.7±0.9	8.6±1.1	8.7±1.1	0.1**

*result of a chi-square test;
**result of ANOVA test;
SD – Standard Deviation.

The simplified version of the questionnaire, used to increase the response rate, did not include questions regarding some confounders. However, the risk factors did not belong to the specific objective of data analysis.

Data Analysis

Prevalence rates of diseases and symptoms were expressed as a percentage with 95% confidence intervals. A chi-square for trend test was applied to identify ordered differences in prevalence of disorders, in 3 points in time [11]. Normality of distributions of continuous variables was tested using the Shapiro-Wilk test. Differences between distributions of continuous variables were analyzed by ANOVA test. Statistical analysis was performed using Statistica 7.1 software and statistical inference was based on the statistical significance criterion: $p<0.05$.

Results

The results showed statistically significant increases in the prevalence of all physician-diagnosed allergic diseases or disorders in years 1993-2002-2007:
asthma 3.4%-4.7%-8.5% (p=0.000001),
obstructive bronchitis 8.4%-20.9%-14.9% (p=0.0001),
allergic rhinitis 9.1%-13.7%-17.4% (p=0.000001),
atopic dermatitis 3.6%-8.4%-8.9% (p=0.000001),
allergic conjunctivitis 4.3%-11.8%-14.9% (p=0.000001),
allergy to pollen 5.9%-12.3%-17.3% (p=0.000001),
allergy to food 5.5%-11.0%-17.0% (p=0.000001), and
allergy to animals: 2.3%-7.9%-12.0% (p=0.00001).

The magnitude of the increases is quite large. Between 1993 and 2007 the relative change in the prevalence of asthma was 150%, of obstructive bronchitis 77%, of allergic conjunctivitis 246%, of atopic dermatitis 147%, of allergic rhinitis 91%, of allergy to pollen 193%, of allergy to food 209%, and of allergy to animals 422%.

Over a 15-year period (1993-2002-2007) the prevalence of cough symptoms has decreased in a statistically significant manner: morning cough 36.4%-33.8%-28.1% (p=0.000001); chronic cough 31.7%-19.8%-15.4% (p=0.000001); dry cough during the night 43.6%-30.4%-27.2% (p=0.000001). The relative changes were negative for morning cough (-23%), dry cough during the night (-38%) and for chronic cough (relative change: -51%). Over the same time period the prevalence of asthmatic symptoms has increased, and the trends were statistically significant: chest wheezing ever 21.3%-27.3%-26.4% (p=0.005); chest wheezing current: 12.3%-14.6%-15.2% (p=0.03); attacks of dyspnea ever: 10.1%-11.4%-13.2% (p=0.01; current attacks of dyspnea: 3.8-5.8%-7.0% (p=0.0004). The respective relative changes were positive for chest wheezing-ever (24%), current chest wheezing (24%), attacks of dyspnea-ever (31%), and current attacks of dyspnea (84%).

The changes in the prevalence of allergic diseases and respiratory symptoms have occurred over the period of a large decline in ambient air pollution in the town of Chorzów (survey area). Fig. 1 shows an approximately three-fold decline in SO_2 and PM_{10} concentrations and a two-fold decline in NO_2 concentration in ambient air, between 1990 and 2007.

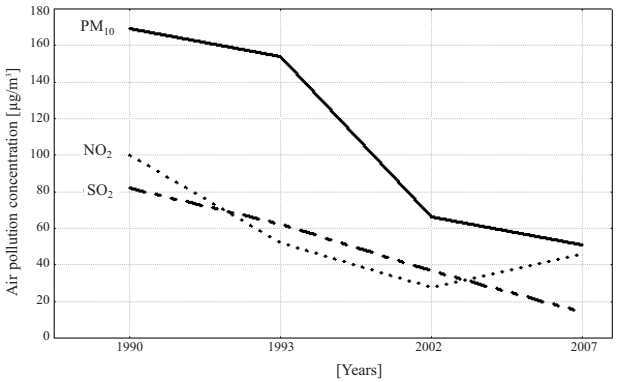

Fig. 1. Trends in ambient air pollution in Chorzów (Poland: 1990-2007).

Separate analyses for girls (Table 2) and boys (Table 3) revealed slight gender-related differences in trends. All trends in the prevalence of ever diagnosed allergic diseases and disorders were positive in both girls and boys. However, only girls did not show a statistically significant trend in the prevalence of obstructive bronchitis (p=0.2). In terms of symptoms only in boys the trend in the prevalence of asthmatic symptoms did not reach statistical significance: chest wheezing (ever – p=0.06, current – p=0.6); attacks of dyspnea (ever – p=0.08, current – p=0.1). The trends of cough were negative and statistically significant in both genders.

Discussion of Results

The results of our studies covering a recent 15-year span showed a statistically significant increase in the prevalence of all allergic diseases diagnosed by physician and respiratory symptoms suggestive of asthmatic tendency. These trends correspond to those seen in the PL-ISAAC studies, and to those found in some other Eastern European countries [1-3, 12, 13]. An at least two-fold increase in the asthma prevalence in USIZ, to the current level of 8.5%, is similar to the 1994/95-2001/02 change reported from Kraków and Poznań studies including early school children [4]. Our investigation is distinct from PL-ISAAC studies by its environmental dimension. Our surveys' time span covered the unique period of unprecedented, at least in Poland, decline in ambient air pollution, thus allowing for "a natural experiment" investigation. Its results are equivocal. The increase in the prevalence of asthma and asthmatic symptoms was accompanied by an approximately two-fold decrease in the prevalence of the symptoms of cough. Such a mirror image (cough symptoms vis-à-vis asthmatic symptoms) could be attributed to an apparent improvement in ambient air quality in Chorzów since 1990. The nature of the relationship between industrial air pollution and atopic diseases is subject to debate [14-18]. Our findings are in line with observations that the decline in ambient air pollution levels is associated with the declining occurrence of nonallergic respiratory diseases and symptoms, but it is not associated with an increase in the incidence of asthma and other allergic diseases among children [16-18].

In Poland, a substantial and unprecedented improvement of ambient air quality since the 1990s took place during the time of socio-economic transition, rapidly affecting many lifestyle elements, from diet patterns to household practices, known as "Westernization." The latter poorly defined factor is perceived as one of the key determinants of an increasing occurrence of allergies [19-24]. However, the protocol we used did not include questions regarding many of those factors, and we cannot discuss their impact on our finding in a direct way. Nevertheless, an interesting finding in our study was that the prevalence of all major non-respiratory allergic disorders diagnosed in children of Chorzów has followed the pattern seen in cases of asthma trends. Rising trends for atopic dermatitis, allergic rhinitis, and conjunctivitis was observed also in the Polish branch of

Table 2. Prevalence (%) of allergic diseases ever diagnosed by a physician and chronic respiratory symptoms in girls aged 7-10 years, in Chorzów (surveys in 1993, 2002, and 2007).

Disease/symptom	Year 1993 n=561 % (95% CI)	Year 2002 n=751 % (95% CI)	Year 2007 n=804 % (95% CI)	p*
Asthma	2.5 (1.2-3.8)	3.5 (2.1-4.8)	6.7 (5.0-8.4)	0.0001
Obstructive bronchitis	8.2 (5.9-10.5)	19.6 (16.7-22.4)	11.7 (9.5-13.9)	0.2
Allergic conjunctivitis	3.2 (1.7-4.7)	7.5 (5.6-9.3)	8.0 (5.9-9.7)	0.0008
Atopic dermatitis	2.3 (1.1-3.6)	8.5 (6.5-10.5)	10.7 (8.5-12.8)	0.000001
Allergic rhinitis	4.1 (2.5-5.7)	10.4 (8.1-12.4)	13.7 (11.2-15.9)	0.000001
Allergy to poolen	5.7 (3.8-7.6)	11.7 (9.3-13.9)	14.5 (11.9-16.7)	0.000001
Allergy fo food	8.0 (5.8-10.3)	13.7 (11.1-16.0)	16.0(13.5-18.6)	0.00003
Allergy to animals	2.5 (1.2-3.8)	9.0 (7.0-11.1)	10.2 (8.1-12.3)	0.00001
Morning cough	36.7 (32.7-40.7)	30.5 (27.2-33.8)	26.9 (23.8-29.9)	0.0001
Chronic cough	29.8 (26.0-33.5)	16.1 (13.5-18.7)	13.8 (11.4-16.2)	0.000001
Dry cough during the night	44.4 (40.3-48.5)	29.5 (26.2-32.7)	26.1 (23.1-29.1)	0.000001
Chest wheezing – ever	18.5 (15.3-21.7)	24.3 (21.2-27.3)	23.7 (20.8-26.7)	0.03
Chest wheezing – current	10.9 (8.3-13.4)	13.8 (11.2-16.2)	15.6 (13.0-18.0)	0.01
Attacks of dyspnea – ever	8.5 (6.2-10.9)	8.1 (6.2-10.1)	11.3 (9.1-13.5)	0.02
Attacks of dyspnea – current	3.2 (1.7-4.7)	4.2 (2.7-5.5)	7.3 (5.4-9.0)	0.0005

CI – Confidence Interval; * chi-square test for trend.

the ISAAC study [12]. As a result, the current population-based estimates of the magnitude of allergic disorders in Poland are not very much different from the figures seen in Western Europe. As shown by ISAAC phase III findings for 13-14-years-old children, the prevalence of rhinitis ranges from 29.7% in Austria to 49.8% in the UK, while in Poland it is 40.4%; the prevalence of hay fever ranges from 17.0% in Italy to 36.7% the in UK, and in Poland it is 31.0%; the prevalence of rhino conjunctivitis ranges from 9.7% in Austria to 16.0% in Germany, while in Poland it is 18.9%; the prevalence of asthma symptoms ranges from 9.4% in Italy to 31.0% in the UK, while in Poland it is 7.8% [2, 3].

A separate issue discussed in relation to time trends of allergic disorders is related to a perceived gender-differential effect. The body of evidence regarding gender-related differences is not yet convincing [23, 25, 26]. The results of our study showed that almost all ever diagnosed allergic diseases and disorders follow an increasing trend in girls and boys. However, as far as asthmatic symptoms are concerned the trends in both chest wheezing and attacks of dyspnea were not statistically significant in boys.

The central question regarding real causes behind increasing trends of allergic disorders seen over a couple of recent decades in many countries is far from being answered. In the case of asthma, two candidate explanations are subject to an ongoing debate: one points to a real increase of occurrence, another points to more effective diagnostic measures due to, for instance, increased "asthma awareness" among parents and health care professionals and/or better availability of diagnostic procedures [27-30]. In Poland, yet another factor has to be taken into account.

Table 3. Prevalence (%) of allergic diseases ever diagnosed by a physician and chronic respiratory symptoms in boys aged 7-10 years, in Chorzów (surveys in 1993, 2002, and 2007).

Disease/Symptom	Year 1993 n= 576 % (95% CI)	Year 2002 n=736 % (95% CI)	Year 2007 n=857 % (95% CI)	p*
Asthma	4.3 (2.7-6.0)	6.0 (4.3-7.7)	10.1 (8.0-12.0)	0.00002
Obstructive bronchitis	8.7 (6.4-11.0)	22.3 (19.1-25.1)	18.1 (15.5-20.7)	0.00004
Allergic conjunctivitis	4.0 (2.4-5.6)	8.7 (6.7-10.7)	9.8 (7.3-11.2)	0.01
Atopic dermatitis	2.3 (1.0-3.5)	7.1 (5.2-8.9)	13.2 (10.8-15.3)	0.000001
Allergic rhinitis	4.5 (2.8-6.2)	12.8 (10.3-15.2)	18.1 (15.4-20.5)	0.000001
Allergy to poolen	6.1 (4.1-8.0)	12.0 (9.7-14.4)	19.0 (16.3-21.5)	0.000001
Allergy fo food	10.1 (7.6-12.5)	13.2 (10.6-15.5)	18.2 (15.6-20.8)	0.00001
Allergy to animals	1.9 (0.8-3.0)	7.3 (5.4-9.2)	13.3 (11.0-15.6)	0.0005
Morning cough	36.1 (32.2-40.0)	36,7 (33.2-40,1)	29.2 (26.1-32.2)	0.002
Chronic cough	33.7 (29.8-37.5)	23.5 (20.4-26.6)	16.8 (14.3-19.3)	0.000001
Dry cough during the night	42.9 (38.8-46.9)	31.1 (27.8-34.4)	28.2 (25.0-31.0)	0.000001
Chest wheezing – ever	23.9 (20.5-27.5)	30.3 (27.0-33.6)	28.9 (25.8-31.8)	0.06
Chest wheezing – current	13.7 (10.9-16.5)	15.2 (12.6-17.8)	14.8 (12.3-17.1)	0.6
Attacks of dyspnea – ever	11.6 (9.0-14.2)	14.8 (12.2-17.4)	15.0 (12.7-17.4)	0.08
Attacks of dyspnea – current	4.3 (2.7-6.0)	7.5 (5.6-9.4)	6.7 (5.0-8.3)	0.1

CI – Confidence Interval; * chi-square test for trend.

For many years an overt clinical manifestation of asthmatic symptoms in young children used to lead to an "umbrella diagnosis" of obstructive bronchitis. This could be explained not only by the influence of nosologic tradition but also by a tendency to delay the final diagnosis until it is certain, or in order to avoid asthma stigmatization. Our findings seem to be in line with all mentioned concepts. We do not have evidence concerning the role of changing putative causal exposures over the last 15 years in Poland and we do not have evidence concerning a changing approach to diagnosis of asthma, triggered by improved diagnostic procedures and by changed health professionals' and public's attitudes to the disease. However, a relative increase in the prevalence of asthma is bigger than a relative increase in the prevalence of asthmatic symptoms; nevertheless the occurrence of both asthma and symptoms has increased. It would be of interest to see if a likely future plateau or even decrease in the occurrence of physician-diagnosed childhood asthma in USIZ corresponds with likewise changes in the prevalence of asthmatic symptoms.

In conclusion our findings suggest that the rising trends in allergic disorders in children of Upper Silesian Industrial Zone reflect both a real increase in the occurrence and a more effective diagnosis of previously underdiagnosed cases. Our observation concerning an increasing asthma trend over the period of significant decrease in environmental pollution supports opinion about irrelevant contribution from exposure to industrial gaseous and particulate ambient air pollution to the development of childhood asthma and other allergic diseases.

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