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16. ABSTRACT

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The University of Akron Study on Air Pollution and Human Health Effects II. Effects on Acute Respiratory Illness

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ABSTRACT. The purpose of this study was to determine the effects of air pollution on acute respiratory illness (ARI). Levels of air pollutants were monitored on a daily 24-hour basis at two schools in Akron, Ohio. The children at each school completed daily diaries which served as a screening mechanism for detecting ARI. Once an ARI was isolated, pulmonary function tests (PFT) were run during the symptomatic phase; once the child became asymptomatic, tests were continued for 2 wk.

The results of this study indicate that SO_2 and NO_2 levels are higher at the school that borders industry. Results of daily diaries indicate a higher incidence of symptoms—especially cough, runny nose, and sore throat—in the polluted area. Pulmonary function tests indicate that respiratory airways are being compromised to a much greater extent at the polluted school, as indicated by significantly reduced levels of forced expiratory volume and maximal mid-expiratory flow as compared to baseline. Recent evidence suggests that frequency and severity of ARI in childhood are related to chronic obstructive lung disease as adults. In lieu of these findings, it is suggested that the levels of SO_2 and NO_2 in urban areas be carefully considered, as they relate to acute subclinical syndromes and chronic clinical respiratory disease.

AIR POLLUTION EFFECTS have been studied in many ways, the most common being the examination of pulmonary function tests (PFT). The association between air pollution and respiratory symptomology has also been studied, but less extensively. Douglas and Waller[1] have shown that increased air pollution effects an increase in the prevalence of lower respiratory infection. Lunn et al.[2] found that increased occurrence of chronic upper respiratory infection was related to air pollution. In a follow-up study, Lunn et al.[3] demonstrated that as air quality improved, the frequency of respiratory infection decreased. Colley and Reid[4] also reported that air pollution is associated with increased frequency of lower respiratory tract infections. It must be noted, however, that air pollution concentrations reported in the British studies were much higher than what is usually reported in the United States. Few studies, however, have examined the prevalence and severity of acute respiratory illness (ARI) and daily symptomology in an urban area where air pollution is a potential health factor. Those studies that have been conducted have not carefully monitored the air quality to which the population was exposed. For this reason, as well as others, there is a paucity of data available regarding cause and effect of air pollutants on ARI in young children.

An earlier report[5] established that the levels of sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) were significantly higher in one school area located adjacent to industry than another that was 4 km away. Sulfur dioxide appears to be absorbed very rapidly in the upper respiratory tract, while NO_2 reaches the small peripheral airways where it exerts its effect. When the annual arithmetic mean of these gases exceeds 100 $\mu g/m^3$, increased risk of acute and chronic respiratory illness and possible changes in pulmonary function[6-8] may result. Even though SO_2 is rapidly absorbed in the membranes of the upper respiratory system, there are still peripheral airways effects via the vagus. Therefore, it is concluded that both SO_2 and NO_2 can affect the dynamics of the respiratory airways.

In 1973 Lebowitz[9] used multivariate statistical techniques to demonstrate air pollution's effect on human health. However, the relationships were causal, but definitive cause and effect was not shown. Lebowitz suggested that an intensive research design would be required to completely answer the questions concerning air pollution and effects on human health, which would include questionnaires, daily diaries, frequent PFT during illness episodes, frequent personal communication with the volunteers involved, and daily monitoring of air pollutants.

Goldsmith and Friberg[10] have stated: "The control of air pollution, and the extent that it is based upon health effects, should be based on the most sensitive groups of persons." Because school children appear to be very sensitive and specifically reactive to the effects of air pollution, this would be a most suitable group to study.

The authors, therefore, chose to study the cause and effect relationship between gaseous air pollutants (i.e., SO_2 and NO_2) and ARI in a stable population of children who attended schools in Akron, Ohio, where air pollutant levels were widely divergent.

METHODS AND MATERIALS

Two schools located in Akron, Ohio were selected for this study. The Seiberling school is located adjacent to an industrial complex and the Betty Jane school is located 4 km east. These schools were selected on the basis of preliminary observations and data from the Akron Region Air Pollution Control Board (ARAPC). The highest levels of SO_2 in Akron have been recorded in the Seiberling area, making it an excellent area for study.

Air pollution measurements. Methods of aerometric measurements used during this study were identical to those described earlier.[5] Total suspended particulates (TSP) suspended sulfate, suspended nitrate, SO_2, and NO_2 were measured daily.

Health data. To determine if a child was contracting an ARI, a daily dairy was initiated. The dairy, which was distributed each day during homeroom by the teacher, was a simple chart; the child checked either yes or no to cough, runny nose, sore throat, chest congestion, cold, and eye irritation. The diaries were then collected by the homeroom teacher for use by the research staff. Prior to initiating the study, all participating homeroom teachers were given a description of the diary and how it was to be used.

On Monday, Wednesday, and Friday of each week, a team of two technicians visited each school. Initially, the diaries were examined for a potential ARI. If runny nose and several other symptoms were checked by a student, they were requested to leave class and go to the clinic, where the student was given a verbal and visual examination by the two technicians to determine the nature and/or severity of the ARI. If an ARI was not found, the symptoms were re-explained to the student and instructions were provided regarding conditions under which a given symptom should be checked. The student then returned to class. If the individual had an ARI, pulmonary function tests were conducted. The techniques for conducting PFT and measuring the spirograms included[5]: forced vital capacity (FVC), forced expiratory volume at 1 sec ($FEV_{1.0}$), and maximal mid-expiratory flow (MMF).

To cross validate the assessment of ARI among the school children, the technical staff exchanged schools and evaluated the existing ARI in both symptomatic and asymptomatic phases. Each symptom was graded from 0 to 4 with increasing severity, enabling objective comparative evaluations. Statistical comparisons were not made on the graded symptoms, but in all cases there was excellent agreement among the technicians concerning presence and severity of individual symptoms.

During the ARI and recovery period (i.e., symptomatic phases A and B, respectively) of an individual who had an ARI, two PFT were conducted every other day until he or she was completely asymptomatic. The individual was then monitored for 2 wk during the asymptomatic phase, which included PFT every other day. The entire process usually included five different series of PFT.

Accuracy of measurement was crucial to the outcome of this study, therefore, brief comments on these techniques follow. Ruled triangles were aligned with the horizontal chart paper lines, which enabled near-perfect vertical lines to be drawn. The 1-sec time line was measured, drawn, and rechecked for accuracy; the 25% and 75% lines for MMF were drawn, measured, and rechecked against the calculated values; and all lines were drawn with very thin, hard lead. These techniques provided a 99% level of accuracy for a given test/re-test calculation for $FEV_{1.0}$ and FVC, and 98% for MMF.

The techniques used to adjust data were similar to those described previously.[5] Briefly, age, height, and weight were used as independent variables to adjust each pulmonary function variable in a multiple linear regression model with forward order of inclusion. This analysis compared all of a given student's symptomatic and asymptomatic PFT variable and effectively used each child as his own control. Other statistical methods employed included the student's t test.

RESULTS

The air pollution levels found in the school areas in Akron have been detailed earlier.[5] Briefly during the school year, mean levels of SO_2 were 77.5 $\mu g/m^3$ and 21.4 $\mu g/m^3$ at Seiberling and Betty Jane schools, respectively, and NO_2 mean levels were 54.5 $\mu g/m^3$ and 36.9 $\mu g/m^3$, respectively. These data confirm the data from the ARAPC and verify that there are large differences in air quality to which the children are being exposed. Figures 1 and 2 show all diary data collected during the school year. Each week's data were totaled for a given symptom at each school and expressed as a percentage of the total reporting students. Although

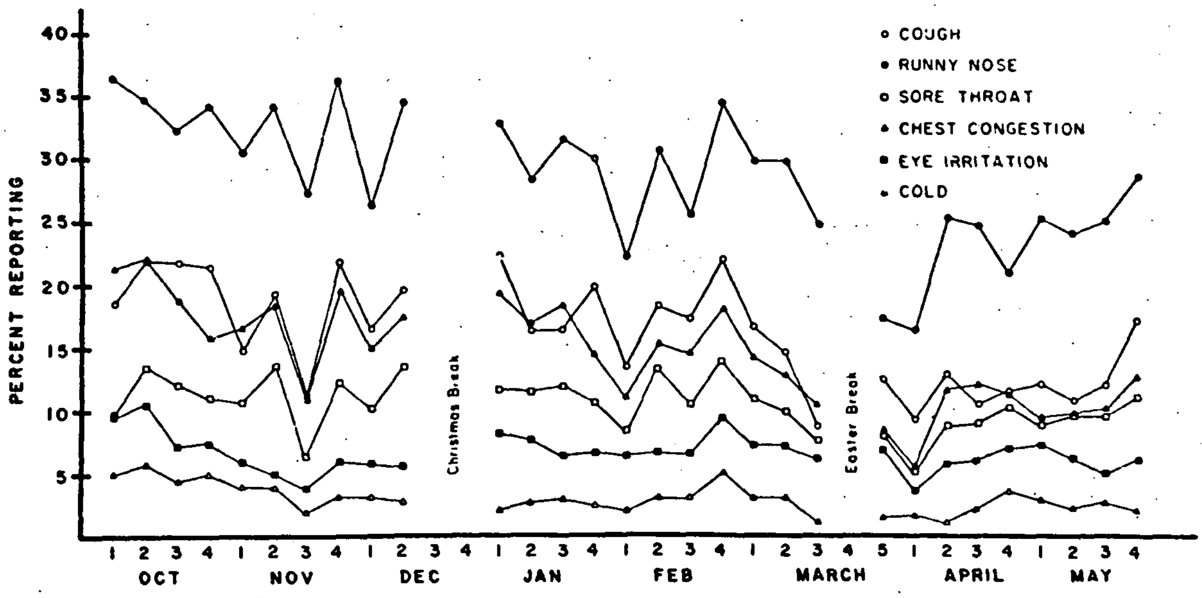

Fig. 1. Daily diary data for children attending Seiberling school.

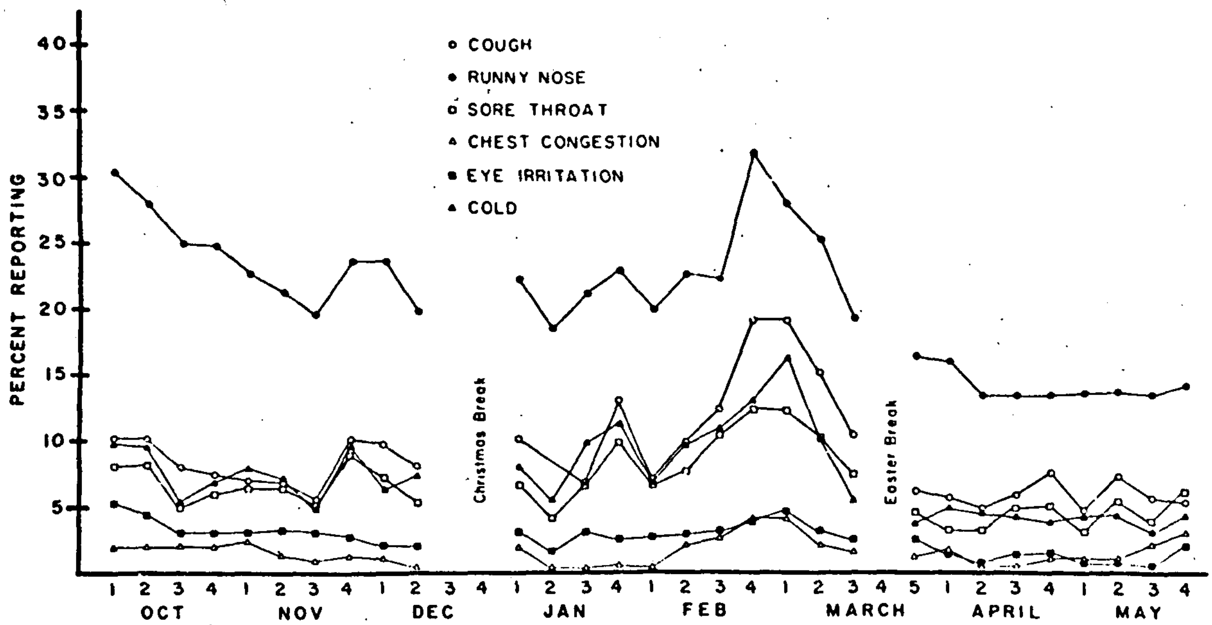

Fig. 2. Daily diary data for children attending Betty Jane school.

these data were not analyzed statistically, empirical observation indicates that the Seiberling students reported any daily symptom twice as often as the Betty Jane students.

Histograms summarizing the results of the PFT during the symptomatic and asymptomatic phases of the ARI are presented in Figures 3-5. The data were obtained from subtracting the specific symptomatic and asymptomatic PFT from the baseline values after adjustment for age, height, and weight. Adjusted data, which provide examples of adjusted means, as well as sex, and the sample sizes involved in the ARI testing, are presented in Tables 1 and 2. The number of students participating in the symptomatic B phase was less than the number who participated in the symptomatic A phase at the Betty Jane school because several became asymptomatic after only 3 days. This might indicate that the Betty Jane students were contracting ARI but that their symptoms were not as prolonged as those at the Seiberling school. Another possibility could be that the subjective evaluations by the technicians at the two schools varied. This is unlikely, however, as ARI assessment by tech-

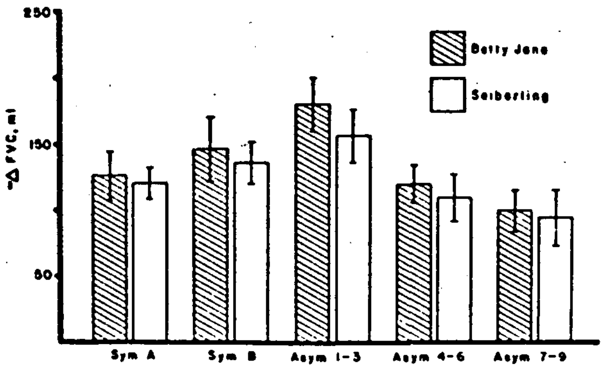

Fig. 3. Comparative differences for forced vital capacity (FVC) during symptomatic and asymptomatic phases of acute respiratory illness (mean ± standard error).

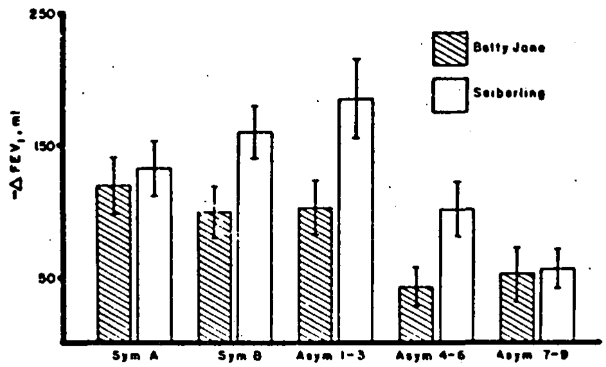

Fig. 4. Comparative differences for forced expiratory volume at 1 sec ($FEV_{1.0}$) during symptomatic and asymptomatic phases of acute respiratory illness (mean ± standard error).

Table 1.—Acute Respiratory Illness and Recovery Period PFT Results for Children Reporting at Betty Jane School

	Baseline	ARI	Δ	*N*	*P*
Symptomatic A phase					
FVC (L)	2.66 ± .03*	2.53 ± .03	.13 ± .02	46	.01
$FEV_{1.0}$(L)	2.16 ± .03	2.04 ± .03	.12 ± .02	46	.01
$FEV_{1.0}$/FVC	0.81 ± .01	0.81 ± .01	.00 ± .01	46	ns
MMF (L/sec)	2.39 ± .09	2.32 ± .09	.07 ± .04	46	ns
Symptomatic B phase					
FVC (L)	2.69 ± .04	2.55 ± .04	.14 ± .024	33	.01
$FEV_{1.0}$(L)	2.17 ± .04	2.07 ± .04	.10 ± .020	33	.01
$FEV_{1.0}$/FVC	0.81 ± .01	0.81 ± .01	.00 ± .005	33	ns
MMF (L/sec)	2.34 ± .11	2.27 ± .11	.07 ± .047	33	ns

NOTE: The symptomatic A phase occurred during acute respiratory illness period; the symptomatic B phase occurred during the recovery period. For complete description, see METHODS.
*Values expressed as mean ± standard error.

nical staff was cross validated (see METHODS).

DISCUSSION

During this study, children suffering from chronic medical symptoms were eliminated from the study, as well as children with physician-confirmed asthma or other chronic respiratory illnesses. The lung function determinations conducted during this study were done with numerous internal quality controls. The students had participated in the study during 2 consecutive years, and were thoroughly familiar with the equipment, technicians, and the FVC maneuver. At this time in the study, nearly all the children were efficient at the FVC maneuver and 3 or 4 efforts were very reproducible. The technicians were personally familiar with each of the students and were able to accurately assess the magnitude of each symptom, and also determine between single symptom allergic reactions and a true ARI. This work was to have been a 2-yr study of ARI, but during the first 5 months (i.e., January-May), the study team was not able to resolve all the technical problems and produce reliable data. Consequently, data collection during this half year established good ARI surveillance techniques and eliminated other problems.

The effects of siblings were carefully considered during the study. At the Seiberling school there were 9 siblings in the study group. During the 1977-1978 school year, there was only one instance when both had ARI. There were

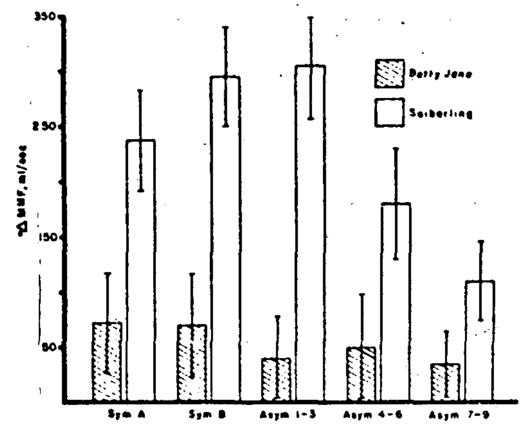

Fig. 5. Comparative differences for maximal mid-expiratory flow (MMF) during symptomatic and asymptomatic phases of acute respiratory illness.

five siblings at the Betty Jane school; during this same school year there was not any case when both were suffering from ARI.

Absenteeism was carefully monitored by examining the daily attendance records for both schools. The fifth and sixth grade populations were approximately the same size and weekly attendance records were similar for both schools. Occasional spikes in absenteeism were seen at both schools, but did not occur at the same time, nor were the spikes related to increased incidence of reported ARI.

The data indicate several interesting observations. (1) The students at Seiberling school are reporting more daily symptoms than those at Betty Jane. This is also exemplified because there are more ARI being reported at the Seiberling school. (2) The PFT data recorded during the symptomatic and asymptomatic phases of an ARI show more airway or airflow obstruction in the Seiberling school, i.e., the PFT variables thought to be most sensitive to airway obstruction are describing the greatest difference, namely $FEV_{1.0}$ and MMF. (3) There is more severe airway obstruction in the Seiberling children and the involved airways require a longer time for recovery. We interpret this to indicate that the airways are affected by the ARI and then further compromised by the effects of SO_2 and NO_2. In effect, one condition was superimposed upon the other.

The symptoms that were reported most frequently by the students were primarily upper respiratory in nature. Therefore, the question arises: "Are such upper respiratory symptoms capable of producing changes in peripheral airways?"

Several studies have shown spirometric changes associated with upper respiratory infection indicating peripheral airway involvement. In some cases this was a spontaneous disease process,[11-13] but in others the disease was initiated by an influenza vaccine.[14,15]

Having established that upper respiratory illness can produce spirometric changes, it must be questioned why the Seiberling children have a greater reduction in $FEV_{1.0}$ and MMF than the Betty Jane children. The populations were carefully matched with respect to socioeconomic status, race, and smoking habits, thus ruling out or minimizing such effects. That the levels of SO_2 and NO_2 are significantly different between the schools could be important factors. We maintain that SO_2 and NO_2 are exerting subtle effects on

Table 2.—Acute Respiratory Illness and Recovery Period PFT Results for Children Reporting at Seiberling School

	Baseline	ARI	Δ	N	P
Symptomatic A phase					
FVC(L)	2.52 ± .036*	2.40 ± .037	.12 ± .012	76	.01
$FEV_{1.0}$(L)	2.05 ± .043	1.91 ± .042	.14 ± .020	76	.01
$FEV_{1.0}$/FVC	0.81 ± .009	0.80 ± .009	.01 ± .006	76	.10
MMF (L/sec)	2.39 ± .068	2.16 ± .076	.23 ± .048	76	.01
Symptomatic B phase					
FVC (L)	2.52 ± .038	2.39 ± .039	.13 ± .016	70	.01
$FEV_{1.0}$(L)	2.04 ± .046	1.88 ± .045	.16 ± .021	70	.01
$FEV_{1.0}$/FVC	0.81 ± .009	0.79 ± .011	.02 ± .008	70	.05
MMF (L/sec)	2.40 ± .072	2.10 ± .072	.30 ± .040	70	.01

NOTE: The symptomatic A phase occurred during acute respiratory illness period; the symptomatic B phase occurred during the recovery period. For complete description, see METHODS.
*Values expressed as mean ± standard error.

the respiratory symptoms of these children, which manifest themselves in baseline PFT data, questionnaire response data, daily diaries, and ARI.

In other studies the superimposition of ARI on existing small airway diseases which were attributed to smoking[16] and chronic obstructive respiratory disease[17] have produced more pronounced lung function changes. To our knowledge, the superimposition of irritating atmospheric gases, such as SO_2 and NO_2, either singly or in combination with the ARI, has not been demonstrated.

All PFT variables were affected by the ARI. In the clean area, reduction in FVC and $FEV_{1.0}$ were the best indicators of dysfunction, while in the polluted area $FEV_{1.0}$ and MMF were more sensitive. At the Seiberling school the differences from baseline for MMF were extremely large when compared to Betty Jane. Hogg et al.[17] suggest that the small caliber of peripheral airways in children may enhance changes in PFT when the children have an ARI, or as in this study, exposed to irritating airborne gases. Both of the above factors would seem to affect the more peripheral airways which would be most sensitive to changes in MMF.

In conclusion, it was thought that the degree of data reliability would be excellent within the framework of this study design, where repeated lung function tests were conducted during a 9-month period of time, as well as daily symptoms and aerometrics. Within this study, the frequency of daily symptoms, as well as syndromes reported by the children, were higher at the polluted school. Repeated lung function tests, which were carefully and systematically carried out during the 9-month school year, further enhanced what we perceive is an air pollution effect, by characterizing reduced airway flow values at the polluted school. These data provide evidence that gaseous air pollutants may exacerbate ARI in fifth and sixth grade children at the Seiberling school.

Follow-up studies of these children are currently underway to determine long-term consequences on lung growth of these levels of SO_2 and NO_2. Many students will also begin smoking; the relative contribution of this will be studied with respect to accumulated effect from the pollutant gases. Other factors, e.g., family history of respiratory disease and a prospective history of respiratory diseases, need to be considered as factors affecting the development of chronic obstructive pulmonary disease.

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