THE OHIO JOURNAL OF SCIENCE

Vol. 75 | MARCH, 1975 | No. 2

THE EFFECTS OF AIR POLLUTION ON PULMONARY FUNCTIONS IN ADOLESCENTS[1]

RICHARD A. MOSTARDI AND RONALD MARTELL

Department of Biology, University of Akron, Akron, Ohio 44325

MOSTARDI, RICHARD A. AND RONALD MARTELL. The Effects of Air Pollution on Pulmonary Functions in Adolescents. Ohio J. Sci. 75(2): 65, 1975.

In an effort to examine the long-term effects of air pollution, 173 junior high students from an urban industrial area were compared with 161 similar students from a rural area. The comparative parameters were vital capacity (VC) and forced expiratory volume ($FEV_{0.75}$). The subjects were separated into sexes since females have lower mean values for these pulmonary parameters than males. These data indicate that there are significant differences between the two groups within all measured parameters. When grouped according to sex or considered as a total group, randomly selected junior high students with similar morphological characteristics show highly significant differences ($P<0.01$) for VC and $FEV_{0.75}$, with higher mean values in the rural group. This suggests that air pollution may have a long-range effect on the pulmonary functions of adolescents living in an industrial urban environment.

Air pollution is a problem confronting urban populations of the world with increasing regularity. One of the disconcerting air pollution problems is its possible effect on the respiratory system. The individual or combined effects of air pollutants on the respiratory system are not completely understood, but they do constitute a source of irritation to pulmonary mucous membranes leading to lowered resistance to pathologic organisms, various forms of pulmonary obstruction, and in some cases death.

Initial work in this area was conducted by Rosenbaum (1961), who showed that army recruits from urban areas suffered more respiratory infections while in the army than those from rural areas. Other work conducted in Japan demonstrated reduced pulmonary functions among children in areas of heavy pollution (Toyahama 1964). In the United States, Ferris (1970) and Shy *et al.* (1970) have shown that vital capacity (VC) and forced expiratory volume (FEV_t) were both reduced in first and second grade children in areas of heavy pollution, and in England Holland *et al.* (1969) has reported reduced peak expiratory flow rates in adolescents living in areas of high pollution.

An examination of such a problem involves suitable geographic locations, as an area of high pollution near an area of low pollution. The city of Barberton, Ohio, has high values of air pollution compared to other Ohio cities as measured by the Akron Air Pollution Control Board. Industry is heavy in the area as are consequent values of dust fall, suspended particles, and sulfur content of the air. In contrast, Eastview Junior High School in Revere, Ohio, located several miles northwest of the Akron city limits and five miles from Barberton, gets prevailing winds from the west which is essentially devoid of industry. Therefore, the area changes from an urban area with heavy air pollution to a rural suburban area where the air is considerably cleaner. We considered this geographic situation to be useful for study of the effects of urban air pollution on pulmonary functions.

In this study we randomly selected a number of junior high school age students from each of two sites and to measure VC and $FEV_{0.75}$ in an effort to determine if air pollution, as measured by dust fall, suspended particles, and sulfur content, has any effect on pulmonary functions.

[1]Manuscript received May 6, 1974 (74-15).

METHODS AND MATERIALS

Subjects. Three hundred and thirty-four junior high school students between thirteen and fifteen years of age (7th, 8th, and 9th grades) volunteered for this study. At U. L. Light Junior High School in Barberton, Ohio, 173 or 26.5% of the total children were selected at random and tested (58 girls and 115 boys). At Eastview Junior High School in Revere, Ohio, 161 or 21% of the students were selected and tested (65 girls and 96 boys). The subjects were randomly selected from a number of classes in each school, with equal numbers coming from the three grades.

Each student was asked to fill out a brief general information questionnaire constructed to obtain information relative to socioeconomic factors, smoking habits, and length of residence in the area.

Data collection. Each subject was tested one time with a Warren G. Collins timed vitalometer with a six liter capacity. This instrument measures VC and FEV_t simultaneously. Each subject was given thorough instruction on the use of the instrument and given several test trials. For the purpose of data collection three trials were recorded and averaged for each parameter. A nose clip was used to direct all of the expired air into the spirometer. The trials were conducted with sufficient time between each test such that the subject was comfortable and had no feeling of dizziness. The spirometer was read to the nearest 10 ml to allow as much accuracy as possible.

In assessing the questionnaire it was determined that subjects who were residents of the areas for less than four years would not be included. This was done since the objective of this study was to examine the long-term effect of air pollution on pulmonary function. This was an arbitrary figure selected by the investigators during the study since no data are available for reference.

In analyzing these data the subjects were compared first by sex and then as a total group. Unpaired "t" tests were used as the comparative statistics.

Pollution Control Data. The degree of air pollution was measured at regular monthly intervals by the Akron Air Pollution Control Board in a number of selected areas. The air pollutants were estimated using deposit gauges to determine the monthly dustfall, lead peroxide candles to determine the sulfur oxide concentrations, and a Hi-volume sampler for suspended particulates. Sampling stations were situated at a number of locations in the area making assessment of air pollution relatively easy. Pollution data for Barberton and Revere sites are given as yearly averages in table 3.

RESULTS

There were no significant differences between subjects at the two testing sites in age, heights, and weight ($P<0.01$). This is an important consideration for it forms the basis for comparative tests of VC and $FEV_{0.75}$ (Ferris and Stroudt 1971). Considering that the two groups are anatomically similar, any observable differences between them with respect to either VC or $FEV_{0.75}$ cannot be attributed to height, age, or weight.

Years of residence vary significantly between the groups with higher longevity of residence in the Barberton area. These mean values are statistically significant but not significant with respect to the outcome of this study, since at the onset of the study a lower limit of four years of residence was established in each geographic area. The mean years of residence for subjects was 12.68 and 9.90 years for Barberton and Revere respectively. Vital data for all subjects tested during this study appears in table 1.

Of paramount importance to this study is the validity of the VC and $FEV_{0.75}$ measurements. Both of these tests are well known and included during extensive examinations of the cardiopulmonary system, (Comroe *et al.* 1955). However, using two tests to evaluate the system, admittedly the sophistication of

TABLE 1. *Vital data for all subjects.**

Group	Barberton					Revere				
	N	Age (yrs.)	Height (cm)	Weight (kg)	yrs. res.	N	Age (yrs.)	Height (cm)	Weight (kg)	yrs. res.
Total Males	115	14.25ns ±.59	169.00ns ±9.20	60.80ns ±12.06	12.70 ±3.01	96	14.40ns ±.62	170.02ns ±9.68	61.07ns ±9.27	9.72 ±3.40
Total Females	58	14.31ns ±.59	162.96ns ±8.76	54.87ns ±10.93	13.17 ±2.70	65	14.44ns ±.55	164.35ns ±5.56	54.91ns ±7.30	10.55 ±3.40
Total Subjects	173	14.29ns ±.59	166.69ns ±9.05	57.98ns ±11.80	12.68** ±2.99	161	14.43ns ±.60	168.20ns ±8.60	58.90ns ±8.94	9.90** ±3.40

*=mean±S.D.
**=$P<0.01$.
ns=not significant.

TABLE 2. *Mean values for vital capacity (VC) and forced expiratory volume* ($FEV_{0.75}$), all data are reported BTPS.

	Barberton mean*			Revere mean*		
Group	VC(ml)	N	$FEV_{0.75}$(ml)	VC(ml)	N	$FEV_{0.75}$(ml)
Total Males	3056.19** ±725.15	115	2373.47** ±594.95	3519.75** ±677.76	96	2951.87** ±526.05
Total Females	2453.43** ±475.95	58	1953.27 ±482.64	2698.30** ±399.90	65	2436.09** ±323.35
Total Subjects	2940.00** ±702.61	173	2305.20** ±570.60	3280.60** ±660.70	161	2735.58** ±518.25

*=mean±S.D.
**= $P<0.01$

the collected data is subject to question. In relation to this, Gaensler (1951) stated that timed vital capacity (FEV_t) produces an accurate assessment of ventilation when extensive research methods are not available and large scale and screening studies are suitable. Since this study is merely serving as a screening device and the only relevant factor during the study was an estimation of the ventilatory capabilities of junior high school age students, these data at least indicate where such differences in ventilatory function occur.

Tests of significance for VC and $FEV_{0.75}$.—Unpaired "t" tests used to compare the groups are shown in table 2. In general there were significant differences between all of the groups tested for both VC and $FEV_{0.75}$. The mean values were higher for the Revere group, indicating that both VC and $FEV_{0.75}$ were significantly greater than for the Barberton group. To assess the effects of smoking on pulmonary function tests of adolescents, subjects who responded affirmatively to the smoking item in the questionnaire were removed from the Total Males group and tests of significance were applied. Fourteen males from Bar-

TABLE 3. *Yearly averages of pollutants collected from the two sites as described in the text. The values include four years of data since this is the minimal residence period set for this study.*

Pollutants-1968	Barberton	Revere
SO_3 content (mg/100cm²/day)	1.0145	0.7632
Dustfall (tons/mile²/month)	47.00	6.00
Total Suspended Particles (μg/m³/24 hours)	109.27	83.30
1969		
SO_3 content	1.2059	0.9175
DUSTFALL	45.1	6.1
Total Suspended Particles	97.36	64.35
1970		
SO_3 content	1.0464	0.8096
DUSTFALL	30.90	5.40
Total Suspended Particles	109.34	76.85
1971		
SO_3 content	1.1100	0.9600
Dustfall	20.3	7.9
Total Suspended Particles	103.82	74.08
1972		
SO_3 content	1.020	0.36
DUSTFALL	25.00	9.20
Total Suspended Particles	100.12	79.95

berton and six from Revere varied significantly with respect to VC and FEV_t ($P<0.025$) with the six Revere males having greater mean values. The remaining 101 Total Males were then retested with the level of significance remaining unchanged ($P<0.01$). Females were not tested since there was only one from Barberton and two from Revere. These test results partially confirm earlier work of Holland and Elliott (1968) who showed that smoking among children had no effect on levels of peak expiratory flow. Figures 1, 2, and 3 are histograms representing total males, total females, and total subjects.

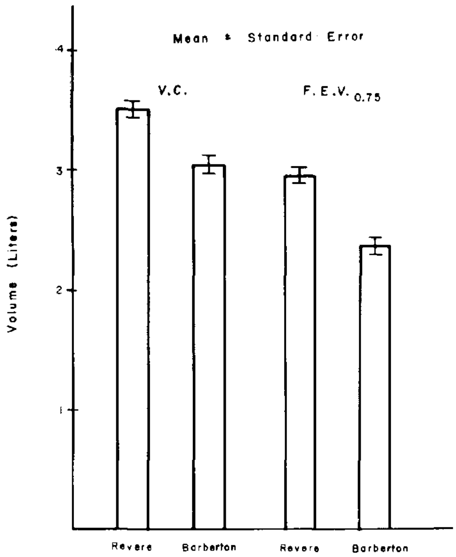

FIGURE 1. Histogram of Vital Capacity and Forced Expiratory Volume for Barberton and Revere males. Data are reported BTPS.

DISCUSSION

This study demonstrates that values for VC and $FEV_{0.75}$ are significantly lower among students at U. L. Light Junior High School in Barberton, Ohio, when compared with a similar sample of students at Eastwood Junior High in Revere, Ohio. Similarly, levels of particulates and chemicals which are known contributors of air pollution are considerably higher in Barberton than Revere.

In evaluating the results of this study, consideration should be given to several potential sources of error. Each student was only tested once during the course of this study and a limited number of tests was utilized. However, the number of subjects used was large and the

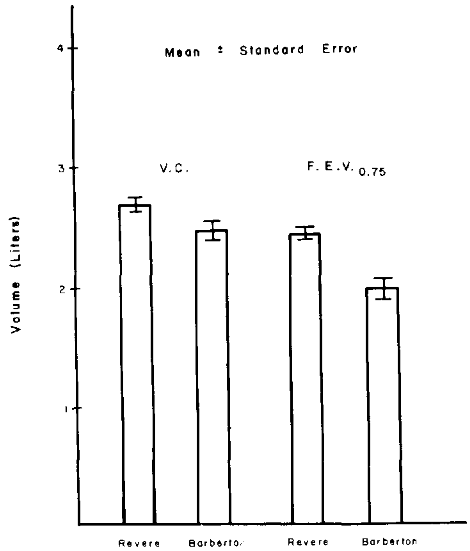

FIGURE 2. Histogram of Vital Capacity and Forced Expiratory Volume for Barberton and Revere females. Data are reported BTPS.

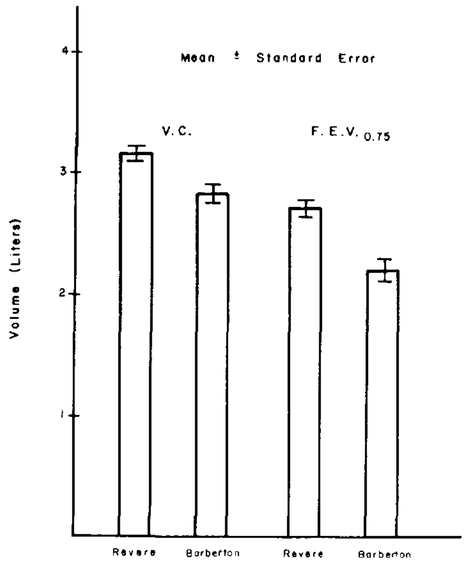

FIGURE 3. Histogram of Vital Capacity and Force Expiratory Volume for Barberton and Revere Total Subjects. Data are reported BTPS.

the two tests utilized are perhaps the most accurate in evaluating pulmonary functions where large numbers are used with screening techniques. It is also understood that one-time or single sampling could lead to errors. In this respect it is known that pulmonary function test results can vary from day to day (Lawther *et al.* 1974) and month by month (Shy *et al.* 1970) with changes in levels of air pollutants. Environmental temperature is also known to exert an effect on lung function, Lebowitz *et al.* (1974). However, the purpose of this work was not to examine the transient pulmonary changes associated with varying levels of pollutants but to determine the long-term effects of residing in an area of high air pollutants.

Errors could also result if the subjects are not uniformly acquainted with and exposed to the equipment. To this extent, careful measures were taken not to expose any of the subjects to the equipment prior to the testing and to give each student similar instructions and trial opportunities. Social class has been suggested by Holland *et al.* (1969) to affect peak expiratory flow rates and that along with other factors exerts an independent and additive effect. Although the questionnaire was not designed to assess specific information concerning socioeconomic factors, it became quite clear during the course of the study by general appearance and personal communication that if any such factor were operating here, it must be limited.

In conclusion, these data support the observations of Shy *et al.* (1970), Holland *et al.* (1969), and Ferris and Stroudt (1971). The levels of pollutants in this study were similar to the levels reported by Shy and Ferris, so these data further support the possibility that environment factors during the early years of life can cause adverse effects which may produce either temporary reductions in pulmonary efficiency or permanent debilitating pulmonary conditions. It is suggested that these environmental factors included dust fall, suspended particles, and air borne chemicals.

Acknowledgment. The authors wish to thank The Akron Air Pollution Control Board for providing yearly levels of pollutants and for their cooperation during this study. This work was supported in part by a University of Akron Faculty Research Grant RG 313.

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