THE RELATION OF AMBIENT SUSPENDED PARTICULATES AND METEROLOGICAL VARIABLES TO FUNCTIONAL PULMONARY IMPAIRMENT[1]

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Daily recordings of ambient temperature, relative humidity, barometric pressure, wind velocity, and suspended particulate concentrations of several ranges of particle size were made over a period of six months on the University of Dayton campus, an urban site. Corresponding daily mean records were made on the pulmonary performance of ten healthy, nonsmoking university students who spent each day in the vicinity of the sampling area. The two sets of physical measurements were fed to the computer for multiple regression analysis. No significant correlation of pulmonary response with particulate pollution was shown. However, there was significant correlation of reduced, resting pulmonary volume with reduced temperature, reduced barometric pressure, and degree of temperature change during 24 hours.

In 1969 the Midwest Research Institute Study (Winfrey, 1969) of air quality in the Dayton area showed that suspended particulate concentrations posed a potentially acute problem in the Miami Valley and that particulate pollution was the major atmospheric problem to be combated. The valley is noted for its rapidly changeable weather patterns (National Weather Service, 1973) and the incidence of functional respiratory distress among many of its inhabitants (Miami Valley Lung Association, 1973).

According to Palmer and Diament (1968) functional respiratory stress mechanisms may relate to obstructive and/or restrictive responses. In the former the bronchial passageways constrict in response to some stimulus. In the latter case the neuromuscular regulation of ventilation may be suppressed. According to Sterling (1967), Widdicombe *et al.* (1962), and McKee (1971) inhalation of small particles can initiate bronchoconstriction. Functional obstructive impairment is most detectable with forced expiratory effort in standard spirometric tests (Gaensler and Wright, 1966) whereas restrictive tendency of a small degree, is most detectable with impedance pneumography of resting pulmonary function (Geddes and Hoff, 1962).

Most studies attempting to relate air pollution to health must be epidemiological and/or statistical in design. Often attempts are made to correlate pollution levels with mortality or morbidity. It has not been resolved whether suspended particulate per se is a serious factor in the health of urban inhabitants, at least healthy, young adults. One difficulty, as Goldstein (1972) indicates, is that pollution and meteorology are so closely related that it is almost impossible to elucidate independent effects on health.

Schoettlin and Landau (1961) observed no significant correlation between asthma attacks and particulate measurement in Los Angeles. Spodnik *et al.* (1966) found respiratory function changes to correlate significantly with outdoor temperature but not with suspended particulate levels. Burrows *et al.* (1968) showed that severity of symptoms in chronic bronchitis was inversely related to temperature and that air contaminants showed no significant relation to these exacerbations.

Spicer and Kerr (1966) showed that measurements of respiratory function in normal subjects and in those with chronic pulmonary obstruction varied significantly day by day, and the authors suspected that air pollution and meteorological changes were responsible. Lawther (1958) presented epidemiological evidence that chronic bronchitis is influenced by day-to-day variations in urban atmospheric pollution. Holland *et al.* (1961) showed a significant correlation between respiratory disease and temperature and atmospheric pollution.

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Greenburg *et al.* (1966), Tromp (1968), and Cohen *et al.* (1972) provided strong statistical evidence relating temperature changes to asthmatic attacks. Spicer and Kerr (1970) found the best correlation involving environmental factors and pulmonary function to be between fraction of predicted functional residual capacity and ambient temperature. More recently, Emerson (1973) who found the most useful test of airways obstruction to be the FEV_1, studied environmental effects on 18 patients with chronic, reversible airways obstruction. Significant correlations were found with temperature in 6 patients, with wind speed in 4 patients, with relative humidity in 4, and with barometric pressure in 3.

Studies involving suspended particulate refer to total suspended particulate, which without knowledge of proportions of various particle sizes may be unrealistic as far as respiratory health is concerned. Ayers and Buehler (1970) state that particles larger than 3–5 μ tend to be deposited in the upper respiratory tract, but small particles which reach the alveoli are not necessarily retained there. Morrow (1960) has shown that some of the smaller particles (0.1–0.5 μ) may be exhaled from the alveoli rather than deposited, the range of maximum deposition being 0.5–3 μ.

This study attempted to further elucidate comparative relationships of ambient particulate pollution and meterorological variables to resting and forced pulmonary responses in normal human subjects.

PROCEDURE

Five male and five female, healthy, nonsmoking university students screened for the study underwent respiratory laboratory tests at the same time each weekday. Screening included determinations for normalcy (for age and sex) in minute volume of respiration, vital capacity, forced expiratory flow rates and hemoglobin content of the blood. The subjects, who spent each day in the general vicinity of the campus sampling site, sat at rest and acclimated to room temperature 2–3 minutes before examination. Tidal volume records were obtained with an impedance pneumograph transducer and physiograph amplifier and recorder. The pneumograph had not been calibrated volumetrically, so tidal volume measurements were recorded as average ohms per breath. An impedance pneumograph record is shown in figure 1. Forced expiratory records were measured with a Warren E. Collins 13.5 liter respirometer. The forced expiratory volume at one second (FEV_1) has been shown to be reliable for detecting obstructive tendency (Gaensler and Wright, 1966, Stein *et al.*, 1966, and Dayman, 1961). Daily means were computed for the ten subjects. The respiratory examinations were performed throughout a six-month period.

The air at a central campus site was sampled daily for suspended particulate with a high volume air sampler at ground level. The Andersen head accessory was used with the sampler (Andersen, 1966). This categorizes the particles into five aerodynamic size ranges: 7 μ and above; 3.3 to 7 μ; 2.0 to 3.3 μ; 1.1 to 2.0 μ; and 0.01 to 1.1 μ. No qualitative analysis of the particles was made and there are few local data indicating the nature of the particulate composition. Future studies will analyze the particles for sulfate and protein. Temperature, relative humidity, barometric pressure, and wind speed were recorded daily at the sampling site. Daily means were computed from readings taken every 2 hours. The differences between the 24 hour maximum and minimum temperature and barometric pressure were also recorded.

The data were treated with multiple linear regression. The two dependent variables, FEV_1 and tidal volume (average ohms per breath), were correlated with the atmospheric independent variables using BMD's biomedical computer program BMDRO2 for multiple regression (Dixon, 1967). In this analysis, correlation of mean respiratory responses was evaluated with atmospheric variables of the same 24-hour period, and also with atmospheric variables of the preceding 24-hour period.

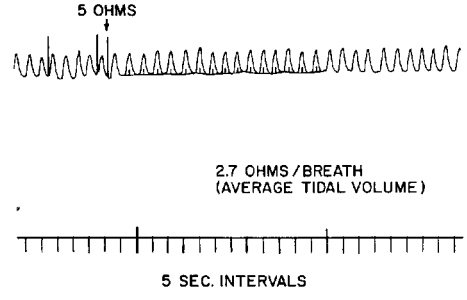

FIGURE 1. Pneumograph impedance record of resting pulmonary function. Calibration spike=5 ohms.

RESULTS

None of the forced expiratory means (FEV_1) showed significant correlation with any of the atmospheric variables. However, the mean tidal volume of the resting pulmonary performance showed significant direct correlation with mean

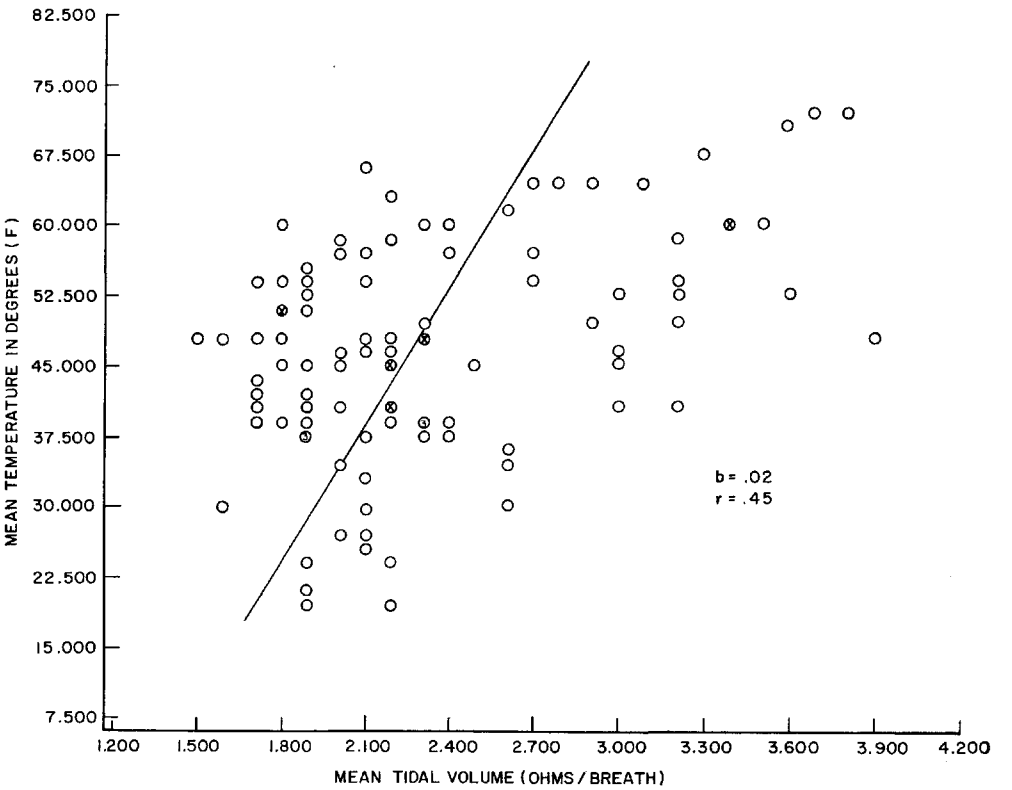

FIGURE 2. Scatter plot and least square regression of mean tidal volume with mean temperature during the same 24 hrs.
⊗— double value
③— triple value

ambient temperature ($P<0.001$). Figure 2 shows this relationship for the same 24 hours. The same atmospheric data with mean tidal volume of twenty four hours later was still significantly correlated ($P<0.001$) (figure 3). In addition, the degree of change in temperature during a 24-hour period showed significant inverse correlation to mean tidal volume for both the same 24 hours and after a 24-hour lag ($P<0.001$). The actual amount of time spent outdoors per subject on given days was not recorded but was variable.

Mean tidal volume also showed significant direct correlation with mean barometric pressure ($P<0.001$), both during the same 24-hour period and after a 24-hour lag. The only other report in the literature indicating a relationship of pulmonary function to barometric pressure is that of Emerson (1973).

No other correlations were significant. There was nothing approaching significant correlation of pulmonary responses to any of the suspended particulate data, whether the particulate was given as total, or for any of the specific range of sizes for the particles. The mean for total suspended particulate was 59.8 ± 24.4 $\mu g/m^3$, the maximum recorded as 148.0 $\mu g/m^3$. Most particles were of the 0.01 to 1.1 μ range with a concentration means of 24.1 ± 8.4 $\mu g/m^3$, and the 7 μ and above range with a concentration mean of 20.4 ± 11.7 fig/m^3. The intermediate ranges of size (3.3 to 7 μ, 2.0 to 3.3 μ, and 1.1 to 2 μ) were negligible; concentration means being 9.0 ± 7.1, 4.4 ± 4.3, and 4.3 ± 6.4 $\mu g/m^3$

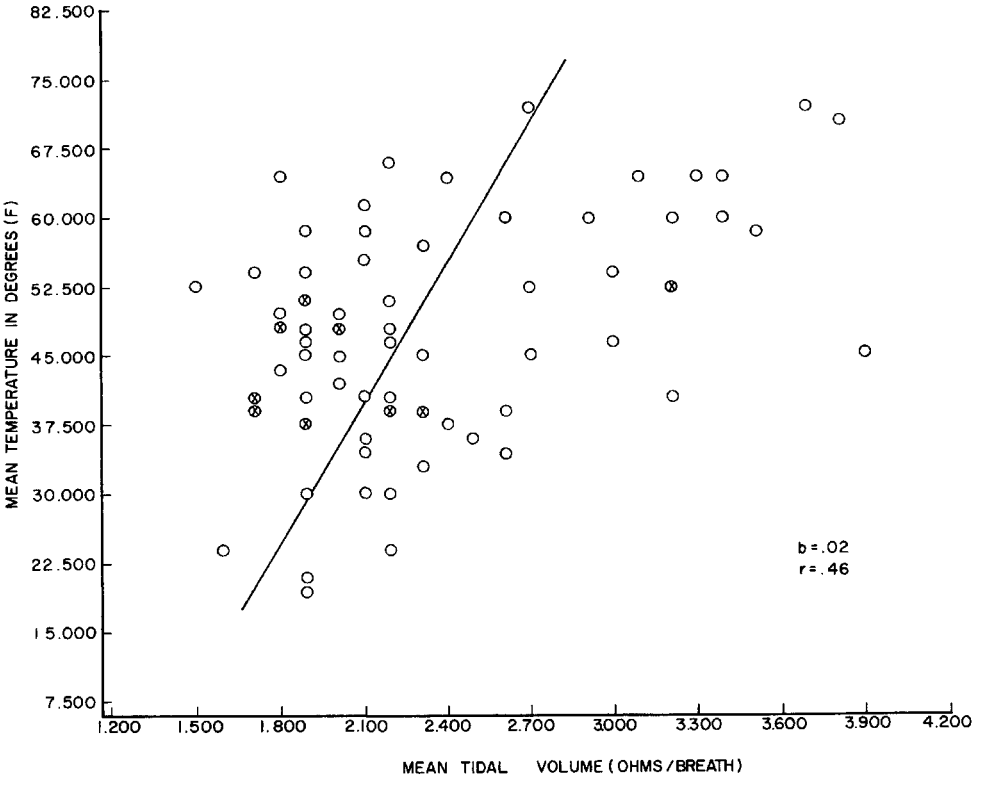

FIGURE 3. Scatter plot and calculated regression line of daily mean tidal volume with mean temperature after a 24-hr. lag.
⊗— double value

respectively.

DISCUSSION AND SUMMARY

The results indicate two generalizations: (1) variables as temperature and barometric pressure show a much greater relationship to pulmonary performance in this study than concentrations of suspended particulates, and (2) resting pulmonary performance has a more significant relationship to temperature and atmospheric pressure than forced expiratory performance. In considering the first generalization it must be realized that the total suspended particulate mean of 59.8 $\mu g/m^3$ for the particular period of study is not formidable, especially in comparison to some means for the Dayton area reported by the Midwest Institute study of 1969 (Winfrey, 1969). In addition when the concentration figures for the size classification of particles are scrutinized it is apparent that the most respirable particles (1.1 to 3.3 μ) represented only 14% of all sample particles.

In the second generalization the absence of significant correlations with forced expiratory performance tends to rule out that the atmospheric variables were promoting any functional obstructive responses. The tidal volume as evaluated by sensitive impedance pneumography did show significant correlation with temperature and barometric pressure. This suggests that the pulmonary stresses were more general and restrictive in nature, possibly through subtle depression of the neuromuscular mechanisms involved in ventilation.

It is concluded that levels of suspended particulate pollution in this study are not capable of producing functional, obstructive pulmonary disturbances in young, healthy non-smokers. Meteorological

factors may be more important, at least in promoting mild restrictions in ventilation. However, studies at another period of time in the same location may yield different results. Also a larger group of subjects with broader population variables (more environmental sensitivity) is desirable. Studies including such extensions are planned.

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