The Relation of Urban Atmospheric Variables to Asthmatic Bronchoconstriction

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A number of experimental studies with animals and humans have indicated that inhalation of particulate matter, ozone, and sulfate is capable of initiating bronchoconstriction, particularly in sensitive subjects (WIDDICOMBE et al., 1962; AMDUR, 1969; and GOLDSMITH, 1969). Therefore, speculation ensues that exposure to certain air pollutants may promote and/or aggravate asthmatic distress. However, several epidemiological studies have suggested that meteorological variables may be more significant than pollution in inducing dyspnea among asthmatics (GREENBURG et al., 1966; TROMP, 1968; EMERSON, 1973; and RAMSEY and BAUNACH, 1975).

The Dayton, Ohio metropolitan complex has been shown to have seriously high levels of suspended particulates (WINFREY, 1969). During the past few years critical levels of photochemical oxidants have occurred also (RAPCA Air Quality Report, 1974), particularly during late summer and autumn. In this region asthmatic complaints are most striking from late summer, through autumn, to winter.

This study was designed to reflect further upon the respective roles of weather variables and pollution fluctuations in promoting the pulmonary bronchoconstriction characterizing asthmatic distress, particularly in an urban location where certain pollutant levels often exceed federal standards. The period of September, October, and November (1974) was selected as a concentrated time segment for the study since this time of year usually contributes some of the highest pollution levels, as well as the notable weather fluctuations typical of seasonal change.

METHODS

Subject selection. Studying a restricted number of asthmatics, but evaluating them intensively on an individual basis day to day, was considered preferable to using greater numbers given less individual attention. Accordingly, a screening process resulted in the selection of seven, male, non-smoking university students, nineteen to twenty one years of age. Each selectee carries the unequivocal diagnosis of bronchial asthma and a background of positive skin testing. Bronchoconstrictive tendencies in each were confirmed by preliminary pul-

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monary performance evaluation which revealed on given days significantly reduced FEV_1, MEFR, MMFR, and reduced flow rates at 10-50% of the VC volume, all of which were reversible with the administration of sympathomimetic agents. During the period of study all were receiving immunotherapy but none relied upon medication.

Pulmonary evaluation. Each afternoon for 3 months three spirograms were produced per subject from forced expirations at hourly intervals into a Warren E. Collins 13.5 liter respirometer. The three values per subject were averaged in respect to FEV_1, MEFR, MMFR, and flow rates (liter/sec.) at 50%, 25%, and 10% of the VC volume. The latter volume/flow rates were calculated by the method of PETERS and FERRIS (1967).

Atmospheric monitoring. All subjects spent each day in the immediate vicinity of a campus site where daily ambient air sampling for suspended particulates ($\mu g/m^3$) with a high volume air sampler was conducted, and ambient ozone ($\mu g/m^3$) monitored with a chemiluminescence analyzer. Pollution data were recorded on a 24 hour basis. In addition the particulates were analyzed for sulfate (JACOBS, 1960), as well as protein (potential allergen) and total organics (CHAMBERS et al., 1958). Daily recordings of ambient temperature, relative humidity, barometric pressure, and wind speed were included.

Analysis of data. The daily means for the 9 atmospheric variables were matched with the daily means for the 6 pulmonary variables in each of the 7 subjects and treated with BMD's biomedical computer program BMDR02 for multiple regression (DIXON, 1967). Independent and dependent variables of the same day were matched, as well as matching independent variables with dependent variables of 24 hours later.

RESULTS

Air quality. During the study period the daily suspended particulate averaged 82.46 ± 35.48 $\mu g/m^3$ (maximum 175), and over half the days showed levels exceeding 75 $\mu g/m^3$, the primary federal standard for annual average. Daily ozone averaged 27.12 ± 18.95 $\mu g/m^3$ (maximum 85) with hourly periods reaching 230 $\mu g/m^3$. Hourly levels of over half the days exceeded 160 $\mu g/m^3$, the federal standard. The average daily sulfate was 3.2 ± 1.82 $\mu g/m^3$ (maximum 7.5), with protein averaging 1.28 ± 0.67 $\mu g/m^3$ (maximum 2.94), and total organics averaging 22.11 ± 9.78 $\mu g/m^3$ (maximum 41.7).

Pulmonary correlations. Because of the necessary caution in interpreting regression-correlation analyses, only a significance of $P = < 0.001$ ($r = > 0.42$) was seriously considered in respect to the multiple regression treatment. Accordingly the daily pulmonary flow rates from four subjects (IV, V, VI, and VII) showed no highly significant relation to any of the atmospheric variables, although subject V did show positive flow rate correlation with daily mean temperature, significant at < 0.01. The only highly significant association between any of the pollution factors and pulmonary flow rates was with respect to subjects I and II where higher ozone levels ironically were associated with higher flow rates (Tables 1 and 2).

TABLE 1.

Values of r for Regressions with a Significance of < 0.001. Independent and Dependent Variables of the Same Day.

Subject	FEV_1	MEFR	MMFR	Flow Rate 50% Vol.	Flow Rate 25% Vol.	Flow Rate 10% Vol.
Independent Variable: Mean Temperature						
I	——	——	0.453	0.451	0.454	——
II	——	——	——	——	0.423	0.497
III	——	0.497	——	——	——	——
Independent Variable: Daily Mean Ozone						
II	——	——	——	——	——	0.425

TABLE 2.

Values of r for Regressions with a Significance of $P = < 0.001$. Dependent Variables 24 Hours Later than Independent Variables.

Subject	FEV_1	MEFR	MMFR	Flow Rate 50% Vol.	Flow Rate 25% Vol.	Flow Rate 10% Vol.
Independent Variable: Mean Temperature						
I	——	——	0.487	0.451	0.483	0.448
II	——	——	——	——	——	0.514
III	——	0.432	——	——	——	——
Independent Variable: Daily Mean Ozone						
I	——	——	——	0.466	——	0.509
II	——	——	——	——	0.472	0.558
Independent Variable: Daily Mean Barometric Pressure						
I	0.476	——	——	——	——	——
III	——	——	0.566	——	——	——

The two tables indicate also that the same two subjects showed a highly significant positive regression of their flow rates with daily mean temperature. Furthermore, since ozone levels have a positive correlation of high significance with mean temperature (r = 0.59), it would appear that the subjects were responding to ambient temperature, not ozone. MEFR values for subject III also regressed significantly with mean temperature (Tables 1 and 2).

Table 2 indicates that subjects I and III experienced highly significant reductions in FEV_1 and MMFR respectively, 24 hours after a depression in barometric pressure. In addition, subjects I, II, and III showed a significant (but less so), inverse regression of their flow rates with mean relative humidity and mean wind speed ($P = < 0.01$, $r = 0.34 - 0.42$). Therefore, estimates from additive correlations indicate that about 30% of the daily flow rate variations in these subjects is due to combined weather factors.

DISCUSSION

Though urban levels of certain air pollutants frequently may supercede present allowable standards, the results of this study suggest that such conditions do not appreciably aggravate asthmatic distress and that ambient chill factors are of greater significance in this regard. This may not be entirely surprising in view of the fact that experimental data with ozone implies that inhalation of 0.6 - 0.8 ppm ($>$1000 $\mu g/m^3$) for 2 hours is necessary to elicit reductions in pulmonary flow rates (SLONIM and ESTRIDGE, 1969).

Exactly how temperature reduction operates in promoting bronchoconstriction is not satisfactorily resolved. SIMONSSON et al. (1967) claim that inhaling extremely cold air (-20°C) stimulates localized vagus reflexes via cough receptors. This may not explain the appearance in this study of bronchoconstrictive tendencies lagging 24 hours behind a more realistic ambient temperature reduction of 15 - 20°C. Might the stress be more general with vagus response to hypothalamic mediation?

CONCLUSIONS

A reduction in ambient temperature and barometric pressure appears to be more instrumental in promoting tendencies to asthmatic dyspnea than do ambient exposures to certain air pollutants even when levels of the latter frequently exceed federal standards.

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