HUMAN BIOCHEMICAL AND PHYSIOLOGIC
RESPONSE TO ACUTE
PHOTOCHEMICAL AIR POLLUTION EXPOSURE

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ABSTRACT

The purpose of this study was to collect and analyze data
relating to the susceptibility of four separate and distinct
population groups to acute, high-level exposures of photochem-
ical oxidant. The groups (or panels) were composed of (1)
college cross-country runners, (2) adult asthmatics, (3) adult
bronchitics, and (4) healthy outdoor workers.

The data were collected during the fall smog season of 1974
in the Los Angeles communities of Covina, West Covina, Azusa, and
and Glendora, California. Panel members were evaluated during
periods of high, intermediate, and low oxidant pollution.

The methods employed in this study included measurements of
numerous biochemical and physiologic parameters as well as sub-
jective responses. Members of all four panels were given com-
prehensive clinical examinations before and after the panel ac-
tivities were conducted. The athletes and bronchitics were
subjected to a series of physiologic tests and discomfort symp-
tom interviews on each of 11 days when oxidant levels were
forecasted to be unusually high or low. The asthmatics and outdoor
workers were given pulmonary function tests and discomfort symp-
tom interviews daily for two weeks regardless of oxidant levels.

Of the data collected, the data from the outdoor worker
panel were most clearly related to air pollution. For example,
eye discomfort, chest discomfort, cough, and phlegm reported by
the panel were positively correlated with concentrations of
ozone. Pulmonary function test scores (maximum forced expira-
tory volume at one second) were negatively correlated with
ozone, but statistically significant only for nonsmokers in the
panel. Chi-square tests of association between the pulmonary
function test scores and the air pollution variables and single
variable linear regressions supported these results. Simple
linear probability regressions, simple LOGIT transformations,
and multivariate regressions of outdoor worker panel data showed
eye discomfort and shortness of breath to be significantly re-
lated to concentrations of ozone.

The analyses presented in this report are based on statis-
tical considerations. They do not specifically address the
medical or public health implications of what was found.

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SECTION 1

INTRODUCTION

The purpose of this study was to collect and analyze data relating to the susceptibility of certain population groups to acute, high-level exposures of photochemical oxidant. Four population groups (or panels) were examined:

1. Trained runners, who may be most resistant to adverse health effects, but who may show physiologic or biochemical impairments when physically stressed.

2. Documented adult asthmatics, who may be unusually sensitive.

3. Chronic bronchitics, who may also exhibit above average sensitivity.

4. Healthy outdoor workers, who because of their constant outdoor exposure may respond to acute oxidant pollution more readily than other healthy segments of the population.

The data were collected during the fall smog season of 1974 in the Los Angeles communities of Covina, West Covina, Azusa, and Glendora. Panel members were evaluated during periods of high, intermediate, and low oxidant pollution.

Previous studies of health effects associated with acute photochemical oxidant exposure have indicated increased eye irritation and coughing at ambient concentrations above 200 $\mu g/m^3$ (0.10 ppm). These studies employed data collection methods which relied heavily on judgements made by recruited subjects. The knowledge gained was limited by the precision and reproducibility of the subjective responses and the lack of objective measurements.

The methods employed in this study included measurements of numerous biochemical and physiologic parameters as well as subjective responses. Data were obtained by means of lung function tests, electrocardiograms, blood samples, nasal swabs, tear samples, and questionnaires. The methods employed and the results obtained are provided in this report.

SECTION 2

SUMMARY AND CONCLUSIONS

PANEL RECRUITMENT AND TESTING

A college cross-country team was recruited to serve as the athlete panel for this study. Seventeen males agreed to participate, although an average of only eight athletes appeared for testing on each of the 11 testing days.

Door-to-door interviewing was used to locate and recruit groups of females to participate on the bronchitis and asthma panels. Fifty-four bronchitics were selected to participate. All were in the 35 to 55 age bracket and all smoked cigarettes. All reported symptoms of chronic bronchitis (defined as more than 50 days of cough and phlegm per year) during the recruitment interviews. The bronchitis panel was tested on 12 days over a period of seven weeks. Only 38 bronchitics attended testing sessions regularly enough for sufficient test results to be entered into the data file for analysis.

Sixty-two asthmatics were recruited. All were in the 21 to 50 age bracket and were nonsmokers. All reported active cases of asthma (defined as 2 to 100 attacks per year with wheezing and shortness of breath) during the recruitment interviews. The asthma panel was divided into four sub-panels which were tested on four successive two-week periods. Only 41 asthmatics participated throughout their assigned two-week periods.

Post Office employees and city workers were recruited for the outdoor worker panel. All were males in the 21 to 50 age bracket. Slightly less than half were smokers. Like the asthma panel, the outdoor worker panel was divided into four sub-panels which were tested on four successive two-week periods. Although 95 workers were selected for the panel, the analysis covers only 85 workers for whom there were sufficient data and no indication of preexisting lung disease.

Members of all four panels were given comprehensive clinical examinations before and after the panel activities were conducted. All were given clinical interviews at the time of the second set of clinical examinations. These interviews replicated the symptom questions asked during recruitment and gathered other health and background information about the panelists.

The athlete and bronchitis panels were subjected to a series of physiologic tests and discomfort symptom interviews on each of the testing days. The athletes undertook the test. both before and after they subjected themselves to stress, i.e., before and after they ran distances of at least two miles. The testing days were scheduled based on forecasts of unusually low or high photochemical air pollution (oxidant levels). The asthmatics and outdoor workers were given pulmonary function tests and discomfort symptom interviews daily for two weeks regardless of oxidant levels.

DATA ANALYSIS

Data from the four panels were analyzed in decreasing order of the amount of information gained. The asthma and outdoor worker panels provided the most information. The asthmatics were expected to be the most sensitive of these two groups; thus, the asthma panel data were analyzed first. A summary of the results of the asthma panel is presented first in this report. The analysis of the outdoor worker panel is presented second. The order of the two remaining panels was suggested mostly by the number of observations available for analysis. A summary of the results of the bronchitis panel is presented third. The analysis of the athlete panel is presented last.

Of the data collected, the data from the outdoor worker panel were most clearly related to the air pollution levels. A likely explanation of this finding is that panel members were breathing outdoor air for several hours while engaged in physical work before they reported for testing. Daily testing was conducted in the afternoon, at the end of the panel members' work shifts. The asthmatics may have been the most sensitive panel, but for a variety of reasons such as placing self-restrictions on activities and remaining indoors during periods of the day when air pollution levels could be expected to be high, the results of analyzing the data from this panel were not as significant. The number of observations obtained from members of the bronchitis and athlete panels were far less than those obtained from the asthma and outdoor worker panels. The bronchitics, like the asthmatics, probably were careful to avoid strenuous activities during periods of the day when air pollution levels were high.

Very few significant results were obtained from the athlete panel. One explanation for this outcome is that the ambient concentrations of air pollution on the days when the panel was tested were not high enough to cause measurable biochemical and physiologic responses in the panel members. An equally plausible explanation, however, is that the data collection was centered on the wrong variables and/or was conducted under the wrong circumstances.

It was probably a mistake to collect data during practice instead of competition and to depend entirely on health data instead of both health and performance data to assess the impact of air pollution. A study conducted by other investigators in which the performance measurements of cross-country runners were used and relationships between air pollution and performance were found is discussed in the overall summary of Section 10 (see Pages 189 and 191). By collecting data during practice instead of competition as was done in the present study, there was no assurance that the panel members achieved maximal exercise on any of the testing days. In addition, the runners' times were not consistently recorded in the present study, so an attempt to relate concentrations of air pollution to performance was not possible.

Other factors which likely reduced the possibility of observing any effects of air pollution on panel members were the following:

- Concentrations of photochemical oxidant were not particularly high on the days when panel data were collected.

- Bronchitis and athlete panel members had to be scheduled for physiologic tests one at a time due to a lack of duplicate sets of test equipment. Consequently, the tests had to be scheduled from mid-morning (hours before photochemical oxidant peaked in the study area) to late afternoon (hours after the peaks had occurred). Such peaks usually occurred around 1 p.m. Not all panel members could be tested during the hours of peak exposure on any testing day.

Three types of variables were included (or at least examined for usefulness) in the analysis of each panel: discomfort symptom variables, physiologic test variables, and air pollution variables. The discomfort variables were qualitative in nature, with panelists answering either "Yes" or "No" to questions about symptoms. The most useful of the physiologic test variables were the pulmonary function variables, maximum forced expiratory volume at one second (maximum $FEV_{1.0}$ or MAXFEV) and maximum forced vital capacity (maximum FVC or MAXFVC). The term "air pollution variables" is used to cover the weather variables, relative humidity and temperature, as well as the air pollutants measured at the times the panel data were collected. Data on ozone (representing photochemical oxidant), nitrogen dioxide, nitric oxide, and carbon monoxide were obtained from the Los Angeles County Air Pollution Control District and used in the analysis. An explanation of why certain air pollutants were included in the analysis, while others were not included is given in Section 6.

The study was primarily concerned with human response to photochemical oxidant. Consequently, the emphasis in presenting the results is on the relationships found between the human response variables and ozone.

Asthma Panel Results

Pearson and non-parametric (Spearman and Kendall) correlation analyses were performed on all four panels. For the asthma panel, the results showed that only eye discomfort (reported at the time of the daily interviews) was consistently and significantly correlated with the air pollution variables, especially with ozone. Pulmonary function variable MAXFEV was not directly correlated with the air pollution variables.

Three methods of association between variables were also applied to the asthma panel data. Simple linear regressions of MAXFEV indicated a significant relationship with relative humidity and temperature, but not with the air pollutants measured. Use of contingency tables showed dependence of having a cold and reporting throat discomfort, headache, nausea, or other discomfort (not specified) at the time of the interview or headache or cough that day. There was no evidence of dependency between having a cold and eye discomfort or chest discomfort at the time of the interview or having a cough that day. Contingency tables also showed no strong evidence between MAXFEV and the air pollution variables.

Simple linear probability regressions indicated that eye discomfort was significantly related to ozone. Selected multivariate linear probability regressions also indicated that eye discomfort was significantly related to ozone.

A sensitivity analysis for asthma panelists having or not having a cold was performed to test whether there was any statistically significant reaction to air pollution. The subset of asthmatics having a cold was examined first. Those not having a cold were examined second.

For the subset having a cold, two primary differences with respect to the whole panel were found. First, the correlations were generally larger, but not significant. Second, the correlation between cough and the concentration of ozone was large and significant, but the correlation was negative. Scattergrams did not indicate any obvious nonlinear relationships.

Comparison of linear probability regressions for the subset having a cold to the linear probability regressions of the whole asthma panel led to an observation that the percentage of variation explained was much larger for the restricted sample. The asthmatics having a cold were more sensitive to ozone in experiencing eye discomfort and headache than the whole panel.

Correlations and linear probability functions were estimated for the asthma subset not having a cold. The estimates were almost identical to those computed for the unrestricted panel.

As stated earlier, the asthma panel was divided into four sub-panels, which were tested over different two-week periods. Differences between the sub-panels could have existed because of differences in their composition due to small sample or self-selection bias. A series of tests was performed to determine whether such differences existed which could not be controlled statistically. In these tests, the dependent variable was either MAXFEV or MAXFEV adjusted for age and height. Difference in variance tests, difference in means tests, and a two-way analysis of variance were the methods employed.

These methods indicated that Sub-panels 1, 2, and 3 were not different from each other, but Sub-panel 4 was distinct. When MAXFEV was adjusted for age and height, the conclusions remained unaltered. Sub-panel 4 was not grouped with the other three sub-panels in subsequent analysis. The evidence was strong, however, for treating the other three sub-panels homogeneously.

The discomfort symptoms were analyzed by computing the proportion of respondents reporting each discomfort symptom on each of the 40 different test dates. The average and maximum values of the air pollution variables were calculated for each date. A LOGIT specification was then estimated using the discomfort symptom as the dependent variable. This functional form is logically consistent with the interpretation of the dependent variables as a proportion since that variable was constrained to fall within the unit interval. Eye discomfort was chosen for analysis because it showed greater correlation to the air pollution variables than the other symptoms. The primary conclusion of the analysis was that the LOGIT provides more realistic predictions at the extremes of the explanatory variables, but the linear probability specification provides reasonable predictions throughout the observed ranges of the air pollution variables.

Multiple LOGIT regressions were estimated using eye discomfort and headache as alternative dependent variables. The multi-LOGIT approach to estimating the probability of these variables was a useful extension of the simple LOGIT specification. There was no evidence of serial correlation when Sub-panel 4 was excluded or when dichotomous explanatory variables were included to control for between group differences. Ozone was directly related to eye discomfort.

Two multivariate regression models were used to explain variations in MAXFEV, while controlling for differences between individuals. First, a model called the Hasselblad model was estimated. That model uses dummy variables to control for differences between individuals. Second, a standard linear

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regression model was estimated which used dummy variables to control for differences between sub-panels. In both cases, none of the air pollution variables had estimated coefficients that were statistically different from zero. The conclusion is that most of the variation in MAXFEV was explained by differences between the individuals in the asthma panel.

Multivariate regression was also applied which used lagged air pollution variables as explanatory variables. None of the lagged air pollution variables contributed to a reduction in the explained variation in MAXFEV.

Outdoor Worker Panel Results

Correlation analyses were performed on the data of the outdoor worker panel. Both parametric and non-parametric correlations were computed and tested for statistical significance. MAXFEV was not significantly correlated with any of the air pollution variables. However, chest discomfort, cough, and phlegm were positively correlated with ozone. Eye discomfort again showed the greatest senstivity to the air pollution variables; it also was positively correlated with ozone.

The correlation analysis was replicated separately for smokers and nonsmokers of the outdoor worker panel. There were more significant correlations for smokers than for the outdoor worker panel as a whole. Headache was not significant for the entire panel but was positively correlated with ozone for smokers. The total number of significant correlations for nonsmokers was smaller than for the entire panel. This was particularly true for the discomfort symptoms, shortness of breath, cough, and phlegm. However, MAXFEV was negatively correlated with ozone and statistically significant only for the nonsmokers. The nonsmoking outdoor workers seemed to be more responsive in terms of decreased lung function to the air pollution variables than any other group examined. These differences between smokers and nonsmokers in the outdooor workers panel indicated that separate treatment of the two groups was necessary.

Single variable linear regressions were estimated with MAXFEV or MAXFEV/MAXFVC as the dependent variable. Most of the air pollution variables were significantly related to MAXFEV for smokers. However, the sign of the coefficent for ozone was positive. For nonsmokers, only ozone was statistically significant and the sign of the coefficient was negative.

Contingency tables were constructed and chi-square tests of association were made between MAXFEV and the air pollution variables. These tests supported the hypothesis of dependence between MAXFEV and the air pollution variables for the outdoor worker panel.

Linear probability functions were estimated using the dichotomous discomfort variables as dependent and the air pollution variables as explanatory. The relationship of eye discomfort with ozone was stronger for smokers than for nonsmokers. Eye discomfort, throat discomfort, chest discomfort, shortness of breath, and cough were all directly related to ozone. There were fewer significant linear probability regressions for nonsmokers. However, discomfort was significantly related to all the air pollution variables for the nonsmokers.

Multivariate linear probability regressions were estimated for the whole outdoor worker panel. The data were restricted to those outdoor workers who reported not having a cold and not taking medication. Those outdoor workers exhibited significant response to the air pollution variables in reporting eye discomfort, chest discomfort, shortness of breath, cough, and phlegm.

The outdoor worker panel was divided into four sub-panels prior to daily surveillance like the asthma panel. Tests were performed to check for small sample or self-selection bias between the four sub-panels. Three different variables were applied in these tests: recorded MAXFEV; MAXFEV normalized by age, height, and whether or not the individual was a smoker; and the ratio MAXFEV/MAXFVC. Tests for differences in sample variances and sample means were performed. The results indicated that only Sub-panel 3 was statistically different from the other three sub-panels.

Difference in variances and means tests were also performed between smokers and nonsmokers. The sample was restricted to panelists not having a cold and not taking medication. The comparison of MAXFEV, MAXFVC, and the ratio MAXFEV/MAXFVC between smokers and nonsmokers indicated there was a significant difference between the two groups. Smokers had lower recorded MAXFEV, MAXFVC, and MAXFEV/MAXFVC scores than nonsmokers. This demonstrated further that the influence of smoking was an important attribute to consider in the analysis of the data.

The discomfort symptoms were analyzed by computing proportions of the symptoms and the means of the air pollution variables for each of the 54 dates of surveillance. Single variable and multivariate regressions were performed using both the linear probability and LOGIT probability specifications.

The simple linear probability regressions resulted in several statistically significant associations. Eye discomfort, throat discomfort, shortness of breath, and cough were significantly related to ozone. Simple LOGIT transformations resulted in significant relationships between eye discomfort and ozone and between shortness of breath and ozone. Multivariate regressions resulted in only eye discomfort and shortness of breath having

consistently significant estimates after a correction for hetero-
scedasticity was applied. And, only ozone remained statistically
significant as an explanatory variable.

Several multivariate linear regression models were applied
which used MAXFEV and MAXFEV/MAXFVC as dependent variables. The
Hasselblad model included dummy variables to control for indi-
vidual differences. The standard linear specification included
age and height or utilized the MAXFEV/MAXFVC transformation to
control for individual differences. A dummy variable technique
was also applied to control for differences between the four sub-
panels. In addition, separate regressions were estimated which
utilized lagged averages of the air pollution variables. The re-
sults of the alternative multivariate regressions showed that
differences in MAXFEV are explained quite well by individual dif-
ferences. But MAXFEV was not statistically sensitive to the air
pollution variables. Moreover, the application of lags resulted
in progressively weaker results the longer the lags.

Bronchitis Panel Results

Both parametric and non-parametric correlation coefficients
were computed for the bronchitis panel and subjected to statis-
tical tests of significance. The pulmonary function variables
MAXFEV and MAXFVC were not significantly correlated with any of
the air pollution variables for the bronchitis panel. Moreover,
when contingency tables were constructed and chi-square tests of
association were applied, this finding was reinforced. The cor-
relation analysis between the qualitative discomfort variables
and the air pollution variables revealed that eye discomfort was
significantly related to ozone.

Single variable and multivariate linear probability func-
tions were estimated for each of the discomfort symptom vari-
ables. The results from the single variable regressions were
generally consistent with those obtained from the correlation
analysis. The multivariate regressions showed no significant re-
lationships between the discomfort variables and the air pollu-
tion variables.

The proportion of panelists reporting each discomfort symp-
tom was computed for each of the 12 dates of testing. The aver-
age level of the air pollution variables was also computed for
each date. The LOGIT specification was applied to selected dis-
comfort symptom proportions. Eye discomfort was significantly
related to ozone, but not to any of the other air pollution vari-
ables. The remaining discomfort variables were not significantly
related to ozone.

Multivariate linear probability regressions using the same
proportions indicated that ozone was positively related to eye

discomfort, chest discomfort, and shortness of breath. Multi-variate LOGIT regressions produced the same results.

Athlete Panel Results

Correlation analysis was applied to the data of the athlete panel. Two sets of correlations were computed, one set before and a second set after the athletes experienced the stress resulting from a practice run of at least two miles. Before running, eye discomfort and other discomfort (not specified) were significantly correlated with ozone. After running, eye discomfort and headache were significantly correlated with ozone.

No significant relationships between MAXFEV and MAXFVC and the air pollution variables were found either before or after running. Correlation analysis, contingency tables, and scatter-grams did not indicate any discernable association between the pulmonary variables and the air pollution variables. Paired difference tests for the means of FVC before and after running and the means of $FEV_{1.0}$ before and after running were made. No significant decrease in either FVC or $FEV_{1.0}$ occurred as a result of running at least two miles.

Linear probability functions were estimated for the discomfort symptom variables. Eye discomfort before and after running was the only discomfort symptom significantly related to ozone.

Further analysis of the athlete panel data did not seem warranted, particularly in light of the small sample size.

CONCLUSIONS

The following major conclusions are supported by the analyses:

● Smoking is an important factor to consider in an analysis of the effects of air pollution on human subjects.

● Outdoor workers are among the most sensitive groups to photochemical oxidant when tested after hours of exposure.

● Outdoor workers who smoke exhibit sensitivity to air pollution differently from outdoor workers who do not smoke.

● Eye discomfort is the most significantly related symptom to photochemical oxidant.

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- The study gave little statistical support to the sensitivity of asthmatics, bronchitics, or college long distance runners.

- Nontraditional regression methods such as LOGIT provide greater analytical flexibility when considering qualitative discomfort symptoms.

- Throughout the panels, most of the variations in MAXFEV can be explained by differences between individuals.

- In analyzing panel data, it is important to control for differences between sub-panels.

- Lagged air pollution information did not significantly contribute to explaining variations in lung function.

SECTION 3

PANEL RECRUITMENT

SELECTION OF STUDY AREA

The study was performed near EPA air monitoring stations in Covina and Glendora. These communities experience high levels of photochemical oxidant pollution and could be expected to provide a range of oxidant levels from below 160 µg/m^3 (0.08 ppm) to above 480 µg/m^3 (0.24 ppm). All panelists lived within six kilometers of the Covina or Glendora monitoring stations as shown in Figure 1. Oxidant levels at the panelists' residences were expected to be similar to those recorded at the monitoring stations.

During the data collection phase of this study, the EPA was conducting environmental health studies unrelated to this project in areas within 3.2 kilometers (2.0 miles) of the monitoring stations as shown in Figure 2. Residents of these areas who were participating in the EPA studies (or who were eligible to participate in them) were not recruited for this project. Specifically, asthmatics and bronchitics were recruited from outside the two 3.2 km areas shown in Figure 2. This was done to maintain total separation of the two study programs. However, outdoor workers and athletes were recruited from the entire area within 6.0 km of the monitoring stations.

ATHLETE PANEL

The members of this panel were required to have the following qualifications:

1. Be trained runners who run one mile or longer distances.

2. Be in proper physical condition for distance running at the beginning of the test program, so that no training effect would be superimposed upon the results.

3. Practice during the afternoon when high oxidant levels would normally occur.

Figure 1. Study area boundaries for athlete and outdoor worker panels.

Legend:

⊕ EPA Air Monitoring Stations

✼ L.A. County APCD Air Monitoring Station

SCALE

0   1   2
(in miles)

0   1   2   3   4
(in kilometers)

Map labels: Foothill Blvd., Alosta Avenue, Loraine Avenue, Citrus College, Citrus Avenue, Grand Avenue, AZUSA, GLENDORA, Arrow Highway, Valley Center Avenue, Azusa Avenue, San Bernardino Road, COVINA, Vincent Avenue, San Bernardino Freeway, WEST COVINA, Glendora Blvd., Francisquito Avenue

Figure 2. Study area boundaries for asthma and bronchitis panels.

SCALE

0		1		2

(in miles)

0	1	2	3	4

(in kilometers)

4. Be willing and able to give the time required
    for the physiologic test-run-physiologic test
    sequence which was expected to take approxi-
    mately one hour each time it was administered.

In addition, it was expected that the panel had to be composed of
consenting adults, because they would be required to run during
periods for which the Los Angeles County Air Pollution Control
District had issued School Health Warnings. School Health Warn-
ings advocate that students from elementary grades through high
school be excused from strenuous indoor and outdoor activities
and could influence colleges to prevent enrolled minors from par-
ticipating in such activities also. These warnings are called
when instantaneous oxidant levels reach 0.35 ppm. The program
specified that a series of physiologic tests be given about 20
minutes before each running exercise and another series be given
about 20 minutes afterwards. Under an optimum schedule, athletes
could start the tesing program at 12 to 15 minute intervals, and
the desired panel of 20 athletes could be tested in four hours
and 40 minutes. This elapsed time was longer than the normal
practice session for most track teams; consequently, the size of
the athlete panel had to be reduced to a number that could be ac-
commodated in a three-hour period.

It was considered essential for the testing program to be
conducted between late August and the end of October because high
oxidant levels are most probable at that time of year. It was
known that high school and college track teams do not train in an
organized way during the summer months, so a year-round joggers'
club seemed preferable. However, local joggers' clubs proved to
be made up of businessmen who jogged for less than an hour in the
early morning or later afternoon, and as a result could not op-
timally meet the requirements of the testing program. High
school athletes could not be used due to the School Health Warn-
ings mentioned previously. A continued search finally produced
an excellent possibility at a community college located in the
study area. A track team was found that closely met the require-
ments of the study. It was learned that if the athletes agreed
to participate, they would not be restricted by School Health
Warnings.

The athlete director and the track coach at Citrus College
in Azusa agreed to cooperate in the study and recommended the use
of the college cross-country team. The athletes were supposed to
train generally at their own convenience during the summer and
were expected to be in proper physical condition when the fall
semester began. Practice sessions were loosely structured but
usually took place in the afternoons. The track coach insisted
that the entire physiologic testing schedule be prepared in ad-
vance and that no testing be done on days of track meets or on
days immediately preceding track meets. The athletes themselves
were interviewed when they reported for practice one week before

fall classes began, and all agreed to participate. The athlete panel was thus composed of all cross-country team athletes who reported for practice on the days when physiologic testing was scheduled. Seventeen athletes participated, and attendance ranged from 7 to 11 with an average daily attendance of 8. Consequently, limiting the size of the panel, so that time would be available to test all of them, proved unnecessary.

Although this cross-county team satisfied many of the requirements of this study, there were several shortcomings. The athletes as a whole were extremely independent and were accustomed to modifying their practice schedules to suit their individual situations. Apparently, this is a normal attitude for the distance runners. It was not possible to get them to attend the testing sessions when they felt that some other practice routine would improve their performance in an upcoming meet. The track coach was interested in winning meets and did not insist that his athletes attend the testing sessions. If a similar panel is required for future studies, it might be advantageous to consider other groups such as military recruits or civil servants who are in good physical condition, but are not restricted because of athletic competition.

BRONCHITIS AND ASTHMA PANELS

These panels are discussed together because the same techniques were used to recruit both. The material presented in Appendix A was used to recruit people who might have been eligible for asthma and bronchitis panel membership. Confirmation of eligibility was based on clinical examinations and in-depth interviews given later by the Lung Association at the Association's Breathmobile. (The "Breathmobile" is a large, totally enclosed trailer, equipped with physiologic test equipment.)

Panelists were required to live outside the 3.2 kilometer areas shown in Figure 2, but within 6.0 km of the Glendora or Covina air monitoring stations. Bronchitis panelists were required to be females between the ages of 35 and 55, to be cigarette smokers, and to report themselves to have chronic bronchitis as evidenced by more than 50 days of cough and phlegm per year (see Appendix A, Bronchitis Panel Questionnaire). A panel of 50 qualified individuals was required. Asthma panelists were required to be females between the ages of 21 and 50, to be nonsmokers, and to have active asthma (2 to 100 attacks the previous year) which had been diagnosed by a doctor (see Appendix A, Asthma Panel Questionnaire). A panel of 60 qualified asthmatics was required. Originally, both of these panels were planned to have equal numbers of males and females, but the quotas of males could not be filled. This was due primarily to the fact that panelists were required to be available for testing on weekday afternoons, when most males in the desired age

categories were at work. Rather than use a very small number of males which might impair statistical significance, the recruiting requirements were changed and all-female panels were used.

Panelists were recruited primarily by door-to-door interviewing. A list of 90 referrals was received from a group of cooperating physicians; however, only 11 of the 90 lived in the designated study area and none of the 11 met all of the requirements for panelists. Local hospitals were cooperative, but supplied lists of individuals who were considered by the project team to be too ill to participate in the study. Most panelists were recruited by a systematic interviewing effort which covered every residence in the study area. The interviewers sought to determine whether the resident's self-reported medical conditions, age, and sex qualified her for the panel and whether she was willing and able to participate in the tests. No clinical or socioeconomic information was collected during the door-to-door interviews.

Each interviewer was supplied with the following materials:

● Interviewer instructions

● Map of the study area

● Interviewer record sheets including a sample that was properly filled out

● Asthma panel questionnaires

● Memoranda to volunteers for asthma panel

● Bronchitis panel questionnaires

● Memoranda to volunteers for bronchitis panel

● Reminder memos to female bronchitis panelists

Copies of all these materials are included in Appendix A. Those pertaining to the asthma panel were printed on blue paper and those pertaining to the bronchitis panel were on yellow paper in an attempt to avoid confusion. The memoranda, which contained a summary of the study test program, were left with each volunteer panelist to remind her of her agreement and to supply her with a telephone number to call if she had any questions. In addition, the memoranda served to remind the interviewers of the details of each testing program.

Two teams of four interviewers each were used, and the recruiting effort lasted for six weeks. Two interviewer team leaders were responsible for dividing the study area among their

team members, and for assuring that all households were approached. The team leaders also made sure that interviews within the city boundaries of Glendora and Covina were conducted only by those interviewers who were licensed to work in those communities. (No licenses were required in Azusa or in the unincorporated areas.) The overall results of the panel recruiting effort are summarized in Table 1. In this tabulation any conversation with a knowledgeable adult is counted as a response. Second contacts were attempted only when a neighbor or friend of the household suggested that it would be worthwhile. This explains the higher percentage of successful second contacts.

TABLE 1.   RESULTS OF ASTHMA AND BRONCHITIS PANELS RECRUITMENT

Sequence of Contacts	Number/Percentage
Doors approached	13,396
Individuals responding to first contact	5,497
Percentage of successful first contacts	41%
Second contacts attempted	1,286
Individuals responding to second contact	645
Percentage of successful second contacts	50%
Overall percentage of successful contacts	42%

The following table shows the numbers of reported asthmatics who were identified during the recruitment. According to these figures, one of every ten contacts resulted in the identification of an asthmatic, and 1 of every 37 contacts led to the identification of an asthmatic in the 21 to 50 age bracket. This is not to suggest that there is an asthmatic in one of every ten households in the general population. Each person contacted was asked for names of friends who might qualify for the panel, and special efforts were made to follow up on all these leads. Most asthmatics seemed eager to participate in the study and made a genuine effort to be available to the interviewer. A much lower number of asthmatics per household would be determined by a survey designed to give results representing the general population.

TABLE 2.   NUMBERS AND AGES OF ASTHMATICS IDENTIFIED
DURING RECRUITMENT

Category	Number Identified
Asthmatics, male and female, age 21 to 50	164
Asthmatics, male, age 21 to 50	66
Asthmatics, female, age 21 to 50	98
Asthmatics, male and female, under age 21 or over age 50	465
Total asthmatics identified	629
Total households successfully contacted	6,142

From the 98 female asthmatics in the 21 to 50 age bracket, a panel of 62 was selected. In general, all nonsmokers with 2 to 100 attacks per year were enrolled if they stated they had wheezing and shortness of breath with asthma attacks, if their asthma had been diagnosed by a doctor, and if they were willing and able to report for the scheduled tests. The panel was divided into four sub-panels which were tested for four successive two-week periods. The panelist attrition rate increased noticeably with the interval between recruitment and testing as shown in Table 3 below, and several panelists withdrew before the sub-panels were formed and testing began.

TABLE 3.   ASTHMA PANEL SIZE AT TIME OF RECRUITMENT
AND ACTUAL TESTING

Sub-Panel	Number Originally Recruited	Number Reporting for Testing	Time Between Recruiting and Testing
1	14	13	1 week
2	15	12	3 weeks
3	14	10	5 weeks
4	15	6	7 weeks

Panelists dropped out for a variety of reasons such as illness, moving out of the area, and changing jobs or working hours, but very few refused without a specific explanation. If a similar study is conducted in the future, it would be advantageous to compensate for the expected attrition by assigning more panelists to the sub-panels scheduled for the last part of the program or by recruiting later for those sub-panels.

Bronchitics were easier to recruit than asthmatics, and 54 qualified panelists were identified after four and one-half weeks of interviewing (compared with six weeks for asthmatics). Table 4 shows the numbers of reported bronchitics identified during the recruitment. These figures cannot be used as an indication of the distribution of bronchitics in the general population. The decision to use an all-female panel was made early in the recruiting program, and, after that time, no specific inquiries were made concerning male members of the households. Nearly all of the respondents were female, since the interviewers were instructed to record information on male bronchitics only when it was volunteered.

TABLE 4. NUMBERS AND AGES OF BRONCHITICS IDENTIFIED DURING RECRUITMENT

Category	Number Identified
Bronchitics, male and female, age 35 to 55	109
Bronchitics, male, age 35 to 55	27
Bronchitics, female, age 35 to 55	82
Bronchitics, male and female under age 35 or over age 55	318
Total bronchitics identified	427
Total households successfully contacted	5,640

Each of the bronchitis panelists were tested on 11 of the 12 testing days over a period of seven weeks. Attendance declined somewhat as the season progressed, but 38 out of the original 54 panelists attended regularly enough for sufficient test results to be entered into the data file for analysis.

Both the asthma and bronchitis panelists were required to report to testing locations as far as four miles from their

homes. At the time they were recruited, they were asked whether they preferred to drive their own cars or have transportation provided. About half of the panelists wished to be transported. Some panelists--particularly the asthmatics--had young children who usually accompanied them to the testing sessions. The testing facilities were deliberately set up to provide a place for children to play without disturbing the tests. This arrangement was explained to the panelists at the time they were recruited.

OUTDOOR WORKER PANEL

The members of this panel were required to be healthy males, aged 25 to 50 years, who lived and worked in or near the communities of Covina, West Covina, Azusa, and Glendora, California. The geographic area is shown in Figure 1. A panel of 80 workers was sought which was divided into four sub-panels of 20 workers each to be tested during four successive two-week periods.

It was hoped that field workers from a large landscape nursery located in the study area could be used, but suitable arrangements could not be made. As an alternative, postal letter carriers and outdoor municipal workers were recruited in the four above-named communities. The postmasters (or their assistants) were most cooperative and recruited the following numbers of male letter carriers: Glendora, 23; Azusa, 12; Covina, 11; and West Covina, 12. All were in the desired age bracket. The city managers of Azusa, Covina, and West Covina gave permission for panelists to be recruited from among their outdoor city workers. The recruits were distributed as follows:

- Azusa   12 (3 each from parks, water, streets, and electric power departments)

- Covina   15 (7 from refuse, 4 from water, and 4 from streets departments)

- West Covina   10 (from various city departments)

This gave a total of 95 panelists who were then divided into four sub-panels.

Ideally, sub-panels should be balanced with equal distributions of ages, work tasks, and work locations. However, the study protocol specified that the workers be tested at the end of the working day, and they had also been promised that no more than 10 or 15 minutes would be required. To accomplish this, all the Glendora workers were assigned to one sub-panel, all Azusa workers another, and so on. Tests were conducted simultaneously at two locations on the work premises--at post offices and at city maintenance yards. This method of grouping

workers into sub-panels was not ideal, but most workers were unwilling to volunteer for a program which required them to drive four or five miles to a central test location, and insufficient equipment and personnel were available to test simultaneously at all seven work locations. The final distribution of the sub-panels is shown in Table 5.

The cooperating postmasters and city managers not only gave their permission for the recruiting of panelists but also made available space for conducting the daily tests. In addition, they permitted employees to take time off from work for the clinical examinations that were conducted before and after each two-week testing session. It would have been difficult to conduct these examinations after normal working hours, and some workers would have been reluctant to donate the necessary amount of their own time.

The letter carriers and some of the maintenance workers were on staggered shifts to permit them to cover Saturdays and Sundays. In addition, the schedule of holidays was different for Federal and city workers; in fact, holidays differed among the three cities. Tests were required to be conducted at the end of the working day, so they were appropriately scheduled even to accommodate irregular work shifts. An attempt was made to test each panelist ten times, and the testing period was extended until this was accomplished whenever possible. The obstacles were not serious, but they should be taken into account by those planning similar studies for the future when participants do not work conventional five-day weeks.

Similar studies which utilize employees in the private sector might have to be set up differently. For example, employers may not wish to pay their employees while they participate in the tests. However, they may allow their employees to have time off without pay and allow the tests to be conducted in a van parked on company premises. Under these circumstances, to compensate for lost wages, it would be necessary to pay workers who participate for the time they spend taking preliminary and post study examinations and two weeks of pulmonary function tests.

TABLE 5. OUTDOOR WORKER SUB-PANELS AND NUMBERS OF PANELISTS

Panel	City	Worker Category	Number of Workers Tested in Each Category	Total Number of Workers in Each Sub-Panel
1	Glendora	Letter carriers	23	23
2	Azusa	Letter carriers	12	24
		Park maintenance	3	
		Water department	3	
		Street maintenance	3	
		Electric power	3	
3	Covina	Letter carriers	11	26
		Refuse workers	7	
		Water maintenance	4	
		Street maintenance	4	
4	West Covina	Letter carriers	12	22
		City mainentance	10	

SECTION 4

FIELD METHODOLOGY--TESTING SCHEDULES

The entire discussion of field methodology is divided into two sections. The first section is an explanation of testing schedules which were different for each of the four study panels. The second section is a discussion of the physiologic test methods. Many of the same tests were run on all panels, so the second section is organized by tests rather than by panels.

ATHLETE PANEL TESTING SCHEDULE

The study protocol required that the following items of data be obtained from each member of the athlete panel:

1. Before and After Running:

   a. Single breath oxygen tests
   b. Volume-time tracing of FVC maneuver
   c. 12-lead electrocardiograms
   d. Blood pressure
   e. Heart rate
   f. Nasal swabs for white cell counts (taken on four days with the option of adding three more days)
   g. Questionnaire information on eye discomfort, throat discomfort, chest discomfort, cough, shortness of breath, and headache
   h. Tear samples for lysozyme determinations

2. Only After Running

   a. Running distances
   b. Running times

3. On Five Occasions After Running

   a. Peripheral venous blood samples for:

      i. Total white cell counts
      ii. Differential white cell counts (including eosinophils)
      iii. Immunoglobulin determinations

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4. On One Occasion Before Running:

    a. Comprehensive clinical interview

    The tests were conducted in the Lung Association's Breath-
mobile and in a supplementary trailer unit both of which were
parked on the Citrus College athletic field. As each athlete
reported for testing the review of discomfort symptoms for the
day of testing was completed. An electrocardiograph was secured
with the athlete in the supine position and pulse and blood
pressure were determined. Following this, the athlete entered
the Breathmobile where anthropometric measurements were made by
the technician. The nurse secured measurements of the tear
volume, employing the Schirmer strip and, at the completion of
this test, obtained swabs of nasal secretions for direct slide
streaking. The athlete then entered a second cubicle in the
Breathmobile where single-breath oxygen tests and forced expira-
tory (spirometry) tests were performed. The time of completion
of this series of tests was recorded.

    The athletes then proceeded to their scheduled run, which
in most instances was 3.2 km (2.0 miles), with stopwatch con-
trol. After the athletes returned from their run, the clock
time was recorded and the athletes immediately underwent elec-
trocardiography, pulse and blood pressure measurement. The tear
test was repeated and additional nasal swabs were taken. The
review of discomfort symptoms was also repeated. On several
visits, but not all, a blood chemistry and blood count determin-
ation was secured by the nurse at this point in the routine.
The subjects again underwent single-breath oxygen tests and
forced expiratory (spirometry) tests. Finally, the time of com-
pletion of the second series of tests were recorded.

    The study protocol supplied by the Environmental Protection
Agency required that tests be performed on five weekdays when
the maximum hourly average oxidant was expected to be 160 $\mu g/m^3$
(0.08 ppm) or less, and on six weekdays when the level was ex-
pected to exceed 480 $\mu g/m^3$ (0.24 ppm). It was assumed that
tests should be conducted during the one or two hours of the day
when these oxidant levels persisted rather than being scheduled
at other times in the day. The athlete panel, however, consist-
ed of a college cross-country team in the midst of their competi-
tive season, and as a result, the coach gave the testing schedule
third priority behind cross-country meets and academic require-
ments. The actual test schedule and corresponding oxidant levels
are given in Table 6.

    As can be seen in Table 6, high oxidant levels occurred
less frequently than predicted during the period when tests
could be scheduled. In 1974 the highest oxidant days occurred
early in the season--before the college semester began. Nasal
swabs and blood sampling were planned for 5 of the 12 testing

TABLE 6. ATHLETE PANEL TESTING SCHEDULE AND CORRESPONDING OXIDANT LEVELS

Date	Time of Day	Oxidant Levels in ppm at Beginning and End of Testing Period†	No. of Athletes Tested Each Day	Nasal Swab Scheduled?	Blood Samples Scheduled?
9/9	9-11 a.m.	0.02-0.08(no forecast)	7	yes	yes
9/10	9-11 a.m.	0.05-0.09 (0.28)	10	yes	yes
9/12	1-3 p.m.	0.17-0.18 (0.25)	7	no	yes
9/19	1-3 p.m.	0.26-0.33 (0.26)	11	yes	no
9/26	1-3 p.m.	0.10-0.13 (0.18)	7	no	no
10/3	1-3 p.m.	0.10-0.11 (0.12)	9	no	yes
10/10	1-3 p.m.	0.09-0.10 (0.10)	5	yes	no
10/17	Noon-3 p.m.	0.08-0.15 (0.15)	8	no	no
10/24	Noon-3 p.m.	0.09-0.10 (0.08)	9	no	yes
10/29	Noon-3 p.m.	0.02-0.02 (0.02)	7	yes	no
11/6	Noon-3 p.m.	0.04-0.05 (0.12)	7	no	no

†Numbers in parentheses indicate forecasted maximum hourly average.

days as indicated on the schedule. Originally, this sampling was planned for two low oxidant and three high oxidant days. The schedule had to be based on forecasted oxidant levels because validated oxidant measurements from the EPA air monitoring stations were not available until several months after the field testing was completed. In many instances the actual oxidant levels were lower than the forecasted levels, and only one of the testing days turned out to be a truly high oxidant day.

The hourly schedule for each testing session was somewhat loosely structured because the athletes refused to make definite commitments. Generally, the testing facilities were ready to receive the first athlete at least 15 minutes before the cross-country workout was scheduled to begin. The athletes did not report as a group for the workout but appeared individually over a two to three hour period depending on their schedules or motivations for the day. As soon as an athlete reported he was given the first series of tests. He then ran two miles and reported back for the second series of tests. Electrocardiograms could be run simultaneously on two individuals, so it was rarely necessary to keep an athlete waiting to begin the tests. The testing facilities remained open until the track coach indicated that no more athletes were expected to appear on that particular day.

Two athletes reported for all the testing sessions and were evaluated as scheduled. For the other 15 athletes (who missed from three to ten sessions each), make-up samples were collected to compensate for absences on days when nasal swabs and blood samples were scheduled.

BRONCHITIS PANEL TESTING SCHEDULE

The study work plan required that the following items of data be obtained from each member of the bronchitis panel:

1. On Each Day of Testing:

   a. Single-breath oxygen test
   b. Volume-time tracing of FVC maneuver
   c. 12-lead electrocardiograms
   d. Blood pressure
   e. Heart rate
   f. Nasal swabs for white cell counts (taken on four days with the option of adding three more days)
   g. Questionnaire information on eye discomfort, throat discomfort, chest discomfort, cough, shortness of breath, and headache
   h. Tear samples for lysozyme determinations

2. On Five Occasions During the Testing Period:

    a. Peripheral venous blood samples for:

        i. Total white cell counts
       ii. Differential white cell counts
            (including eosinophils)
     iii. Immunoglobulin determinations

3. On One Occasion Upon Entry to the Program

    a. Comprehensive clinical interview

The tests were conducted in the Lung Association's Breathmobile, which was parked in a central location. The panelists were given appointments for their tests at ten minute intervals between the hours of 11 a.m. and 2:50 p.m. and 4 p.m. to 7:50 p.m. The late time period was necessary to accommodate panelists who worked during the day and could only come in the evenings. Panelists were furnished transportation to the Breathmobile unless they preferred to drive their own cars. Each panelist was sent a letter explaining the scheduling of the tests. A copy of this letter appears as Appendix B to this report. When the panelist arrived at the Breathmobile, a trained interviewer administered the questionnaire for symptoms of discomfort pertaining to that day. An electrocardiograph was then performed with the panelist in the supine position, and pulse rate and blood pressure were recorded. Next, anthropometric measurements were made. The nurse secured tear samples and nasal swabs. On five of the visits to the unit, bronchitic subjects also underwent blood sampling for WBC and differential counts, and immunoglobulin determinations.

The study protocol required that tests be performed during the week, on five days when the maximum hourly average oxidant was expected to be 160 $\mu g/m^3$ (0.08 ppm) or less, and on six days when the level was expected to exceed 480 $\mu g/m^3$ (0.24 ppm). Panelists were notified of each test by telephone during the afternoon or evening of the day preceeding the test. To accomplish this it was necessary to make an oxidant forecast at noon for the maximum level to be reached in the study area on the following day. Most routine forecasts, such as those made by the Los Angeles County Air Pollution Control District, are made at 9 a.m. and give the expected maximum oxidant level for that day in an area which is considerably larger than the area of interest in this study. Thus, the routine Los Angeles County forecasts could not be used, and special forecasts had to be made under these more demanding conditions. The situation was complicated even further because real time or next day validated oxidant data were not available from the EPA air monitoring stations in the study area to use in checking the forecasts.

Nonetheless, plans proceeded to choose testing days based on oxidant forecasts specially prepared for the project.

Tests for the bronchitis panel were scheduled only for Tuesdays, Wednesdays, and Fridays. Mondays could not be used because some of the meterological information on which the forecasts were based was not available on weekends. The test equipment was used for the athlete panel on Thursdays. The actual testing schedule and corresponding oxidant levels are given in Table 7. A comparison of the forecasted and actual maximum hourly oxidant levels shows that as in the case of the athlete panel, the forecasts were only marginally helpful in selecting appropriate testing days. In future studies of this type, it would probably be just as effective to set up the entire testing schedule in advance and not bother with forecasts and the accompanying problems of having to give panelists such short notice for testing. Also, testing should probably be restricted to three or four hours in the afternoon when high oxidant levels are experienced. At the maximum testing rate of six persons per hour, a panel of 18 to 24 could be tested in this key period. If a larger panel is required, the test equipment could be duplicated to permit simultaneous testing of two persons, or perhaps sub-panels could be tested on different days. Either of these modifications would, of course, almost double the cost of working with a bronchitis panel.

ASTHMA PANEL TESTING SCHEDULE

The study protocol required that the asthma panel be divided into four groups. These groups were tested over successive two-week periods, one group per period, during the season of highest photochemical oxidant exposures. A panelist was tested once every weekday over the two-week period of coverage for his group. The daily tests consisted of three measurements with a Sted-Wells Spirometer of one-second forced expiratory volume ($FEV_{1.0}$) and a series of interview questions relating to symptoms of discomfort. The testing equipment was located in a central facility and panelists reported there at assigned times. Transportation was provided unless the panelists wished to drive their own cars. Tests were conducted between the hours of 10 a.m. and 7 p.m. with as many as possible being scheduled between 1 p.m. and 4 p.m. when oxidant levels were expected to peak. Up to 12 persons per hour could be tested and attempts were made to schedule 12 persons per hour during the peak oxidant period. However, many panelists had commitments that prevented them from reporting during the preferred testing period. If all 62 panelists could have reported during the preferred testing period, additional equipment would have been required to accommodate them.

TABLE 7. BRONCHITIS PANEL TESTING SCHEDULE AND CORRESPONDING OXIDANT LEVELS

Date	Time of Day	Oxidant Levels in ppn at Beginning and End of Testing Period†	No. of Bronchitics Tested Each Day	Nasal Swab Scheduled?	Blood Samples Scheduled?
9/4††	Noon-7:30 p.m.	0.13-0.29 (0.30)	22	yes	yes
9/5††	Noon-8:30 p.m.	0.20-0.34 (0.33)	19	yes	yes
9/18	11:30 a.m.-8:00 p.m.	0.09-0.34 (0.32)	33	yes	yes
9/24	11:30 a.m.-7:30 p.m.	0.01-0.17 (0.35)	37	no	no
9/25	11:00 a.m.-8:00 p.m.	0.02-0.19 (0.26)	38	no	no
10/1	11:30 a.m.-7:30 p.m.	0.01-0.19 (0.35)	31	no	no
10/9	11:00 a.m.-8:00 p.m.	0.05-0.13 (0.08)	29	yes	yes
10/15	11:00 a.m.-8:00 p.m.	0.05-0.13 (0.19)	30	no	no
10/16	11:00 a.m.-7:30 p.m.	0.02-0.14 (0.22)	29	yes	yes
10/18	11:00 a.m.-8:00 p.m.	0.01-0.15 (0.09)	29	no	no
10/22	10:00 a.m.-8:00 p.m.	0.01-0.13 (0.07)	34	yes	yes
10/25	11:30 a.m.-7:30 p.m.	0.01-0.14 (0.12)	31	yes	yes

†Numbers in parentheses indicate forecasted maximum hourly average.

††Half of panel tested on each of these days; most of panel tested on remaining days.

Detailed clinical examinations of each panelist were conducted before and after her two-week examination period. The examinations were conducted in the Lung Association's Breathmobile which was parked in a central location. Anthropometric measurements and a pulmonary function evaluation consisting of spirometry, single-breath oxygen test, and body plethysmography were included. A questionnaire for symptoms of discomfort was also completed at that time. The study protocol did not specify that any particular oxidant levels should prevail during these detailed clinical studies, but to the extent possible, they were conducted on low oxidant days so that, for baseline setting purposes, health effects due to air pollution might be minimized. A clinical interview questionnaire was administered after the field studies were completed.

OUTDOOR WORKER PANEL TESTING SCHEDULE

The study work plan required that the outdoor worker panel be tested in the same way as the asthma panel (see above) with one exception—that the tests be conducted at the end of the work day. The only feasible way of accomplishing this was to set up the test equipment on the work premises so that the workers could be tested immediately on returning from the field. The workers would not have volunteered to participate if they were required to take much extra time to report to a remote test location. Testing was performed simultaneously at two different locations, and the testing locations were different for each of the four study groups. Tests were done between 10 a.m. and 6 p.m. with most being performed between 2 p.m. and 4 p.m. It was necessary to test six days a week because many workers were on irregular shifts so that Saturdays were covered. Because of this fact, not all panelists in each study group were tested on the same days. The testing was continued until each panelist in the group had been tested ten times; then the equipment was moved to a new location for the convenience of the next group.

Detailed clinical examinations of each panelist were conducted before and after the two-week examination period. Procedures were identical to those described above for the asthma panel. The workers were permitted by their employers to take time off from their jobs to go to a central location for these examinations. No more than six panelists could be handled in an hour so it would have been impossible to schedule everyone for clinical examinations at the end of the working day.

SECTION 5

FIELD METHODOLOGY--PHYSIOLOGIC TEST METHODS

Generally, the same physiologic test methods were used on all test subjects regardless of which panel they belonged to. For this reason this section is organized by tests rather than panels. The single exception was spirometry which was done by one method for athletes and bronchitics and by another method for asthmatics and outdoor workers. Both methods are described.

LUNG FUNCTION TESTS

Single-Breath Oxygen Test

This test was performed on each study day for the athletes and bronchitics and as part of the detailed clinical examinations, before and after each two-week testing period, for the asthmatics and outdoor workers. Each subject performed the single-breath oxygen test in the standing position with a nose clamp in place; a flanged valve was introduced into the mouth. Each subject was asked to breathe normally for a few breaths through a low dead space 9-way valve which was opened to room air. The needle valve assembly of a rapidly responding nitrogen analyzer was interposed between the mouthpiece and the 9-way valve. After stablizing, the subject was asked to exhale completely, and hold his breath briefly while the valve was switched, opening the inspiratory port to a reservoir containing 100 percent oxygen. The subject was then instructed to inspire fully and deeply, within ten seconds, to his total lung capacity. He then expired through the expiratory port, now opened to an Ohio 780 electronic spirometer, at a slow but constant rate (generally between 0.5 and 0.8 liters/second as monitored on a recording device) through the next ten seconds to the residual volume position. Expired volume and expired nitrogen concentration were simultaneously recorded on the horizontal and vertical axis of a Hewlett-Packard XYZ ink recorder. Readjustment of the nitrogen concentration baseline permitted recording of subsequent trials on the same graph paper. The technician observed the tests as they were completed, to select the best determination of the three or to request further trials if needed. The tracings were examined by the chief technician; values for the Delta N_2 (750 to 1,250 ml) of exhalation, the

volume exhaled at the Phase III inflection point, and the total volume exhaled were then recorded for later data processing.

Volume-Time Tracing of FVC Maneuver

This test was performed on all panelists. For the athletes and bronchitics, the test was performed on each study day. For the asthmatics and outdoor workers, the test was performed during the detailed clinical examinations before and afer each two-week testing period.

The test was performed with the panelist in the standing position and a clean disposable mouthpiece was employed. The subject was instructed to reach maximum inspiration. Then while placing the mouthpiece between his lips and closing them tightly on the tube, he was instructed to exhale as rapidly and force-fully as possible, until he could express no more air. The test was repeated at least four additional times until the technician felt the three maximal expiratory efforts had been achieved. Volumes and flow rates identified by this procedure were on mag-netic tape as well as on oscillographic paper. In the analysis of tape outputs, the "best breath" was selected (Massey format) for the recording of spirometric values included in the final printout.

$FEV_{1.0}$

This measurement was made on the outdoor workers and asth-matics using Sted-Wells type spriometers manufactured by Collins. Before the start of the testing program the spirom-eters were compared with each other and with the Ohio 780 electronic spirometer in the Breathmobile to make sure that all gave equivalent readings. Agreement among them was within ex-perimental error, and no correction factors had to be devel-oped. Values for $FEV_{1.0}$ for three trials were hand calculated from the instrument charts using conventional techniques and were subsequently corrected to BTPS. Measurement of FVC was not specified in the study protocol, so the test subjects were not instructed to finish their expiration completely so that values for FVC could also be calculated. For all tests, the spirom-eters were located indoors in air conditioned rooms which re-mained at approximately the same temperature for the entire two-week testing period.

Body Plethysmography

This test employed the Ohio 3100 system. Flow volume loops defining box pressure versus mouth pressure, and box pressure versus airflow were generated, according to techniques standard-ized by Du Bois. Subjects were seated inside the plethysmograph with a nose clip in place and asked to breath calmly through the

mouthpiece-pneumotachograph assembly. After venting the box several times, over one to two minutes, box pressure equilibration was achieved as indicated by the superimposition of a few tidal excursions of box pressure on the oscilloscope. Subjects were then asked to pant, with the shutter open at the end expiratory breathing position. After several panting demonstrations, one or two acceptable loops were retained on the lower half of the storage oscilloscope. The shutter was then automatically closed at the end of expiration, and one or two box pressure versus airway pressure loops were retained on the upper half of the oscilloscope. The shutter was then reopened. The tangents of the angles formed between the horizontal axis and the loops stored on the oscilloscope were then determined by aligning parallel lines of a plastic ruled overlay device (swung in front of the oscilloscope) to the appropriate portion of the loops. After appropriate alignment, the tangents were read directly off the plastic device. Each series of panting maneuvers was repeated through four additional tests. The readings of the five tangents, with the shutter open and closed, were then recorded. Airway resistance and thoracic gas volume at functional residual capacity were calculated from each set of tangents read from the oscilloscope. The independently measured box calibration factors, apparatus dead space, and apparatus resistance were also entered into the equations. The box pressure calibration was corrected for a flow volume displacement of the subject, using the subject's weight in kilograms and assuming a tissue density of one gram per cubic centimeter. For each set of measurements, specific airway conductance was calculated. In the analysis, the calculated airway resistance and thoracic gas volume for the five attempts were averaged.

Calibration of Pulmonary Equipment

The nitrogen analyzer was calibrated, employing pure oxygen (0% nitrogen) and humidified room air (78.9% nitrogen). The spirometers were calibrated for volume with a special syringe (1.5 liter volume). Flow calibrations were performed with an external rotameter while air was supplied to the spirometer at ten liters per second by means of another spirometer and a Scotch Yoke mechanism.

The body plethysmograph was calibrated according to the instructions of the Ohio 3100 Operations Manual. A reciprocating pump delivered a calibrated 50 cc stroke for box pressure verification. Electronic calibrations for mouth pressure and flow were externally validated with a U-tube water manometer and a flow-generating device in conjunction with a Fischer-Porter rotameter.

HEART FUNCTION

Blood pressures, heart rates, and 12-lead electrocardiograms were taken using standard techniques on a Hewlett-Packard electrocardiograph. The unit was secured with subjects in the supine position. Calibration and electrode placement were performed according to standard instructions. (Calibration and testing were performed by the same technician on almost all occasions.) In the instance of athlete studies, the time delay from completion of the exercise until completion of the post-exercise electrocardiogram was recorded.

Interpretation of the electrocardiograms was completed by a board certified cardiologist who prepared a report according to the format shown in Appendix C. This report was subsequently coded and tabulated in digital form. The coding system used in translating the cardiologist's report to digital form is provided as Appendix D.

HEMATOLOGY

CBC and Differential

Subjects were seated and the nurse performed a standard venipuncture in the antecubital area, after skin cleansing. Specimens were secured by the B.D. vacutainer system. One tube with anticoagulant was sequestered for cooling, and was used for the determination of blood count and differential count. The second tube was allowed to clot and then was centrifuged. The serum was decanted into a separate identified container. These were frozen and transferred to the CLMG lab for determination of immunoglobulins, which was performed by methodology described below. CBC's and differentials were performed by the hematology laboratory of the St. Frances Hospital in Lynwood, California, using Coulter Model S counter for WBC, RBC, Hgb, Hct, MCV, MCH, and MCHC. Differential counts were made in the standard way using the hemocytometer. The reporting format is reproduced in Appendix E.

Nasal Smears

Subjects were seated and the nurse applied a swab to the nasal membranes, securing secretions from one or both nares. These were then applied to a clean glass slide which had been identified with the subject's I.D. number, the date of collection, and whether the specimen was secured before or after outdoor exercise. A standard fixative was then applied to the slides, and they were packaged and transported to the laboratory of the St. Frances Hospital for staining and examination for eosinophils. Findings were reported as "negative," "few" (<5%), "moderate" (5 to 20%), and "many" (>20%).

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Immunoglobulins

Serum samples were obtained as described above under "CBC and Differential." Quantitative analyses were performed by the Bio-Sciences Laboratories of Los Angeles. Immunoglobulins A, G, M, and D were determined by radial immunodiffusion using the method perfected by Fahey, and immunoglobulin E was determined by a radio immunoassay method using I^{125} as the labeling agent. A kit obtained from Pharmacia Diagnostics was used for the IgE determination.

MISCELLANEOUS

Tear Samples

The lysozyme concentration of tears was determined by the Proctor Foundation for Research in Ophthalmology at the San Francisco Medical Center of the University of California. Tear samples were obtained according to directions supplied by them. Test subjects were seated quietly in the Breathmobile. A measured strip of test paper (Schirmer Strip) was carefully inserted in the conjunctival sac of each eye. The nurse observed the saturation of the test strip through a five minute period of time. The strips were then removed (earlier if fully saturated), and the distance of saturation (and the time to complete this if less than five minutes) was recorded for each eye. The removed strips were divided at the line of saturation, and a strip placed into a glass vial and sealed with a screwtop lid. Each vial was labeled to indicate whether taken from the right or left eye and the time of day, as well as being identified as to the subject's practice of wearing glasses during usual activity. The sealed vials were then mailed to the Proctor Foundation in batches. Enzyme content was determined by standard methodology under the direction of Dr. Ernest K. Goodner.

Reports of Discomfort

On each testing day every panelist was questioned about symptoms of discomfort, amount of smoking, and respiratory illness. Responses were recorded on the form shown in Appendix F. The questions were asked at the beginning of the testing period except in the case of the athletes who were questioned twice-- before and after the race. Generally, a single interviewer or a pair of interviewers recorded the responses for each panel. Efforts were made to keep techniques as uniform as possible among interviewers, but it is possible that slight differences might have occurred between panels. It is believed that no biases due to questioning techniques occurred within a given panel.

Clinical Interview Questionnaire

A sample questionnaire is shown in Appendix G. This questionnaire was administered to all panelists by a trained interviewer at the end of the field testing portion of the study. The study protocol originally required that the questionnaire be administered at the first comprehensive clinical examination, but questionnaire clearance was not received in time for this to be done. It is believed that the change in the time of administration did not affect the accuracy of the responses.

SECTION 6

RAW DATA FILES

During the course of this study, raw data were obtained in
a variety of ways--on magnetic tape, from instrument charts or
oscilloscope screens, from handwritten records, or on printouts,
from computers that were integral components of automated analy-
tical systems. Ultimately all data items were put into digital
format and tabulated. The collected tabulations were bound into
a Raw Data Book. One copy of this book was sent to the EPA Pro-
ject Officer for the Agency's reference. This chapter of the
final report lists the items included in the data book and,
where appropriate, explains how the data were obtained.

PHYSIOLOGIC DATA

Anthropometric and Miscellaneous

The following items are included:

- Height (inches)

- Weight (pounds)

- Systolic BP

- Diastolic BP

- Pulse rate

- Running time for race (minutes) - athletes only

- Date and time of day measurements were made

For each member of the asthma and outdoor worker panels there
are two sets of measurements--before and after the two-week
period of daily testing. For each member of the athlete and
bronchitis panels there are measurements for all of the testing
days or for as many of the days as the subject was present. In
addition, for the athlete panel, blood pressure values and pulse
rates were measured before and after each race.

Body Plethysmography

The data file includes the average five attempts for the following:

- Thoracic gas volume (liters)

- Airway resistance (cmH_2O/liters/second)

- Date and time of day measurements were made

These measurements were made on the asthma and outdoor worker panelists during the clinical examinations which were performed before and after the two-week periods of daily testing. There are, therefore, two sets of measurements for each member of the asthma and outdoor worker panels. These measurements were not made on the athletes or the bronchitics, however.

Closing Volume

The following items were tabulated for the best of three efforts:

- Volume (ml) at the beginning of the plateau

- Difference in nitrogen percentage at 1,250 ml and 750 ml

- Vital capacity minus closing volume divided by vital capacity $\left(\frac{VC-CV}{VC}\right)$, expressed as a percent

- Vital capacity (ml), labeled "slow VC" to differentiate it from VC

- Medication during past four hours - yes or no

- Ease of reading closing volume

- Quality of tracing

- Date and time of day measurements were made

In instances where the ease of reading the closing volume was recorded as "poor," the $\frac{VC-CV}{VC}$ values were judged to be invalid and were not included in the data file. There are two sets of measurements for each member of the asthma and outdoor worker panels which were made before and after their two-week daily testing periods. For each member of the athlete and bronchitis panels, there are measurements for each of the testing days

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when the subject was in attendance. Measurements were made
before and after the race for the athlete panel.

Pulmonary Function

The data file contains the following items for the asthma
and outdoor worker panels:

- Corrected $FEV_{1.0}$ (liters) - three maneuvers

- Date and time of day measurements were made

Measurements were made once on each day of the two-week daily
testing period.

For the athlete and bronchitis panels, more sophisticated
electronic equipment was used and the following items were tabu-
lated for the best of three maneuvers:

- Forced expiratory flows averaged over the fol-
  lowing volume fractions: 0.2-1.2%, 25-75%,
  75-85%, 75-90%

- FVC (liters)

- $FEV_{1.0}$ (liters)

- $FEV_{1.0}/FVC$

- $FEV_{3.0}$ (liters)

- $FEV_{3.0}/FVC$

- Maximum forced expiratory flow rate

- Time of maximum flow (seconds)

- Forced expiratory flow rates at the following
  volumes: 25%, 50%, 75%

- Date and time of day measurements were made

Measurements were made at every testing session that the
athletes and bronchitics attended. For the athletes, measure-
ments were made before and after each race.

Electrocardiographs

Twelve-lead electrocardiograms were run at every testing
session for the athletes and bronchitics. In addition, the
athletes were tested before and after each race. After being
interpreted by a cardiologist, these results were reported on

the form shown in Appendix C and converted to digital form in accordance with the coding sheet shown in Appendix D. All these items were tabulated in the raw data files. Provision was made for recording two conclusions from the cardiologist; however, in most cases there was only one conclusion. No electrocardiograms were obtained on members of the asthmatic or outdoor worker panels.

<u>Hematology</u>

Venous blood samples were obtained from each member of the athlete and bronchitis panels on five of the testing days. The following measurements were performed and are included in the data files:

- White blood count

- Red blood Count

- Hemoglobin (gm)

- Hematocrit (%)

- Mean Corpuscular Volume (μ^3)

- Mean Corpuscular Hemoglobin ($\mu\mu$g)

- Mean Corpuscular Hemoglobin Concentration (%)

- Differential white cell count including segmented neutrophiles, band forms, metamyelocytes, myelocytes, total neutrophiles, eosinophiles, basophiles, lymphocytes, and monocytes

- Absolute white cell counts as calculated from WBC and differential

- Platelets (normal, increased, decreased)

- RBC (normal, anisocytosis, hypochromia, poikilocytosis, polychromasia)

- Immunoglobulins A, G, M, and D (mg%)

- Immunoglobulin E (units/ml)

- Eosinophiles from nasal smears (negative, few, moderate, many)

- Date and time of day measurements were made

Lysozyme in Tears

Tear samples were obtained from each member of the athlete and bronchitis panels on 5 of the 11 testing days. Samples from the athletes were obtained before and after the race. The following items are tabulated:

- Schirmer, right eye (mm)

- Schirmer, left eye (mm)

- Lysozyme, right eye (µg/ml)

- Lysozyme, left eye (µg/ml)

- Date and time of day measurements were made

QUESTIONNAIRES

Daily Symptom

Daily symptom records were maintained for each subject for each testing day and were recorded before and after the race for the athletes. Samples of the record forms have been given previously in Appendix F. All of these records are included in the raw data files.

Clinical Interview

The clinical interview questonnaire (Appendix G) was administered once to each subject. Responses to all 55 questions are included in the data files along with the subject's birthdate, age, sex, and height.

AEROMETRIC DATA

The aerometric data file contains relevant aerometric data obtained from Federal, state, and county agencies operating air monitoring stations in or near the study area. Specifically, the file contains data collected by the following air monitoring stations:

- EPA station 0841 at Glendora, California

- EPA station 0842 at Covina, California

- California Air Resources Board station at Temple City, California

• Los Angeles County Air Pollution Control
  District station at Azusa, California

The Glendora, Covina, and Azusa stations are located within the study area (refer again to Figure 1). The Temple City station is located several miles to the west. Based on these locations and on comparisons of the data collected by the four stations, it was decided to rely primarily on the aerometric data from the Azusa station in the analysis of the health information. Two factors led to this decision. The Azusa station offered the largest number of observations of the air pollutants of interest to this study. In addition, the levels of oxidant and oxides of nitrogen measured at the Azusa station tended to fall between those measured at the Glendora and Covina stations. A further discussion of these factors and an explanation of the oxidant correction factor is given in Appendix H of this report.

The air pollution variables included in the analysis were ozone (O_3), nitrogen dioxide (NO_2), and nitric oxide (NO). The values were obtained as hourly averages measured in parts per hundred million and converted to parts per million (ppm) before being entered into the raw data files. Ozone provided the usual estimate of oxidant. Both prominent oxides of nitrogen were included; nitrogen dioxide, which was known to be toxic to the lungs, and nitric oxide, which was considered to be much less toxic than NO_2, but which served as a control for spurious results. Carbon monoxide (CO) was also included in the analysis because of the commonality of its sources in the study area with those of oxidant and oxides of nitrogen. The values of CO were obtained as hourly averages measured in ppm; however, these values were inadvertently entered into the raw data files in terms of ppm x 100.

Twenty-four hour averages for sulfur dioxide, total suspended particulates, suspended sulfates, and suspended nitrates were entered into the raw data files, but were not included in the analysis. The values for these pollutants were generally below the air quality standards for 24 hours and, therefore, were not expected to cause measurable biochemical or physiologic response.

Relative humidity data were not available from any monitoring station in the study area. Values in the raw data files were estimated by assuming that the dew points in the study area were identical with dew points measured at Ontario International Airport, which is located about 17 miles southeast of the study area. Relative humidities were calculated from temperatures obtained in the study area and from the assumed dew points. Values are recorded as "high" (>75%), "medium" (50 to 75%) and "low" (<50%). Temperature data were obtained as hourly averages measured in degrees Fahrenheit from one of the two EPA air monitoring stations.

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The aerometric data were obtained (and relative humidity was estimated) for each hour between 7 a.m. and 9 p.m. for each day health information was collected. As a prelude to the analysis of the health information, a correlation matrix was developed for the air pollution variables in order to determine the extent of collinearity between these variables. The matrix is presented in Table 11 in Section 7.

SECTION 7

DATA ANALYSIS--ASTHMA PANEL

The analyses presented in this section and in Sections 8, 9, and 10 are based on statistical considerations and do not specifically address the medical or health aspects of the work. The results obtained should provide starting points for interpretation by persons trained in medicine and epidemiology. The analyses of the four panels are presented in decreasing order of the information gained:

- Section 7 - Data analysis of the asthma panel

- Section 8 - Data analysis of the outdoor worker panel

- Section 9 - Data analysis of the bronchitis panel

- Section 10 - Data analysis of the athlete panel

The asthma and outdoor worker panels provided similar levels of information. Although the asthmatics were considered to be potentially the more sensitive of the two groups to the effects of air pollution, it might be said that more interesting results came from comparing the effects of air pollution on smokers versus the effects of air pollution on non-smokers in the outdoor worker panel. The order of the bronchitis and athlete panels was suggested mostly by the number of observations available for analysis.

STATISTICAL DESCRIPTION OF THE ASTHMA PANEL

It is recalled that the asthma panel was composed of non-smoking females in the 21 to 50 age bracket. Although 62 females were selected for participation, four dropped out before daily surveillance began. The remaining individuals were divided into four sub-panels which were tested for four successive two-week periods. Table 8 summarizes the composition of the sub-panels. Of the 58 females assigned to the sub-panels, only 41 participated throughout the testing periods.

The analysis of the asthma panel data is restricted to the discomfort symptom, pulmonary function, and air pollution variables measured during daily surveillance. Comprehensive clinical examinations of each panelist were conducted before and after the panelist's testing period and a clinical interview questionnaire was administered after the field studies were completed. The information obtained from the clinical examinations and the interview was used to verify the presence of asthma symptoms and was not meant to be a part of the daily surveillance data base. The information indicated that all of the panelists actually had symptoms of asthma as they reported during recruitment.

Description of the Variables

The discomfort symptom variables were measured with the form shown in Appendix F. These variables were qualitative and, consequently, had to be coded for analysis. "Yes" responses were coded to equal unity and "No" responses were coded with zero. A statistical profile of the discomfort symptom variables is given in Table 9A. The variables were:

- EYES (eye discomfort)
- THROAT (throat discomfort)
- CHEST (chest discomfort)
- HEADACHE
- NAUSEA
- OTHER (other discomfort)

- HEADACHE EARLIER
- BREATH (shortness of breath)
- COUGH
- PHLEGM
- COLD (bad cold)
- MEDICINE

The smoking variable included on the form was not applicable to the asthma panel, since all of the panelists were nonsmokers.

The pulmonary function variable used in the analysis was MAXFEV, which was the maximum $FEV_{1.0}$ score of three maneuvers attained each day by each panelist. The AGE and HEIGHT of each panelist were recorded as age in years and standing height in inches. These data were used to adjust (or normalize) the MAXFEV scores prior to analysis. A profile of the MAXFEV, AGE, and HEIGHT variables is given in Table 9B. MAXFEV is shown in hundred liters (liters x 100).

TABLE 8. COMPOSITION OF THE ASTHMA SUB-PANELS

Characteristics	Sub-Panel 1	Sub-Panel 2	Sub-Panel 3	Sub-Panel 4†	Total
Subjects enrolled in panel (all females)	13	12	10	6	41
Current cigarette smokers	0	0	0	0	0
Subjects 21 to 30 years old	7	6	2	2	17
Subjects 31 to 40 years old	5	2	6	2	15
Subjects 41 to 50 years old	1	4	2	1	8
Subjects with 12 or more years of school completed	10	9	8	5	32
Race other than white	3	2	1	1	7

†Age missing for one panelist in Sub-Panel 4.

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TABLE 9A.   STATISTICAL PROFILE OF DISCOMFORT SYMPTOM VARIABLES MEASURED DURING ASTHMA PANEL SURVEILLANCE

VARIABLE: EYES = Eye discomfort now

MEAN	= 0.338	RANGE	= 1.000
VARIANCE	= 0.224	MINIMUM	= 0.000
KURTOSIS	= -1.525	MAXIMUM	= 1.000
STD DEV	= 0.474	VALID OBS	= 379
SKEWNESS	= 0.688	MISSING OBS	= 0

VARIABLE: HEADACHE EARLIER = Headache earlier today

MEAN	= 0.288	RANGE	= 1.000
VARIANCE	= 0.205	MINIMUM	= 0.000
KURTOSIS	= -1.114	MAXIMUM	= 1.000
STD DEV	= 0.453	VALID OBS	= 379
SKEWNESS	= 0.941	MISSING OBS	= 0

VARIABLE: THROAT = Throat discomfort now

MEAN	= 0.325	RANGE	= 1.000
VARIANCE	= 0.220	MINIMUM	= 0.000
KURTOSIS	= -1.434	MAXIMUM	= 1.000
STD DEV	= 0.469	VALID OBS	= 379
SKEWNESS	= 0.751	MISSING OBS	= 0

VARIABLE: BREATH = Shortness of breath today

MEAN	= 0.317	RANGE	= 1.000
VARIANCE	= 0.217	MINIMUM	= 0.000
KURTOSIS	= -1.374	MAXIMUM	= 1.000
STD DEV	= 0.466	VALID OBS	= 379
SKEWNESS	= 0.791	MISSING OBS	= 0

VARIABLE: CHEST = Chest discomfort now

MEAN	= 0.401	RANGE	= 1.000
VARIANCE	= 0.241	MINIMUM	= 0.000
KURTOSIS	= -1.834	MAXIMUM	= 1.000
STD DEV	= 0.491	VALID OBS	= 379
SKEWNESS	= 0.405	MISSING OBS	= 0

VARIABLE: COUGH = Cough today

MEAN	= 0.507	RANGE	= 1.000
VARIANCE	= 0.251	MINIMUM	= 0.000
KURTOSIS	= -1.997	MAXIMUM	= 1.000
STD DEV	= 0.501	VALID OBS	= 379
SKEWNESS	= -0.026	MISSING OBS	= 0

VARIABLE: HEADACHE = Headache now

MEAN	= 0.219	RANGE	= 1.000
VARIANCE	= 0.171	MINIMUM	= 0.000
KURTOSIS	= -0.146	MAXIMUM	= 1.000
STD DEV	= 0.414	VALID OBS	= 379
SKEWNESS	= 1.363	MISSING OBS	= 0

VARIABLE: PHLEGM = Phlegm today

MEAN	= 0.753	RANGE	= 1.000
VARIANCE	= 0.187	MINIMUM	= 0.000
KURTOSIS	= -0.615	MAXIMUM	= 1.000
STD DEV	= 0.433	VALID OBS	= 186
SKEWNESS	= -1.178	MISSING OBS	= 6

VARIABLE: NAUSEA = Nausea now

MEAN	= 0.042	RANGE	= 1.000
VARIANCE	= 0.041	MINIMUM	= 0.000
KURTOSIS	= 18.789	MAXIMUM	= 1.000
STD DEV	= 0.201	VALID	= 379
SKEWNESS	= 4.565	MISSING OBS	= 0

VARIABLE: COLD = Bad cold today

MEAN	= 0.050	RANGE	= 1.000
VARIANCE	= 0.048	MINIMUM	= 0.000
KURTOSIS	= 15.048	MAXIMUM	= 1.000
STD DEV	= 0.219	VALID OBS	= 379
SKEWNESS	= 4.134	MISSING OBS	= 0

VARIABLE: OTHER = Other discomfort now

MEAN	= 0.409	RANGE	= 1.000
VARIANCE	= 0.242	MINIMUM	= 0.000
KURTOSIS	= -1.860	MAXIMUM	= 1.000
STD DEV	= 0.492	VALID OBS	= 379
SKEWNESS	= 0.371	MISSING OBS	= 0

VARIABLE: MEDICINE = Medicine today

MEAN	= 0.530	RANGE	= 1.000
VARIANCE	= 0.250	MINIMUM	= 0.000
KURTOSIS	= -1.983	MAXIMUM	= 1.000
STD DEV	= 0.500	VALID OBS	= 379
SKEWNESS	= -0.122	MISSING OBS	= 0

Available aerometric data were selected to correspond to the times of daily surveillance. A profile of the air pollution and weather variables used in the asthma panel analysis is given in Table 9C. The variables were:

- OZONE (estimate for oxidant)
- No (nitric oxide)

- CO (carbon monoxide)
- HUMID (relative humidity)

- NO_2 (nitrogen dioxide)
- TEMP (temperature)

The air pollution variables were obtained in hourly averages measured in ppm (CO in ppm/100). Relative humidity was estimated by hour and expressed in percent. Temperature was obtained as hourly averages measured in degrees Fahrenheit.

Missing health and aerometric observations were few and not serious. NO_2 readings contained the greatest number of missing observations and, where only one hour was missing, values were estimated by averaging the NO_2 values for the hour-before-test and hour-after-test.

A problem arose due to the lack of enough equipment to test all members of the asthma panel simultaneously. Panel members had to be scheduled for testing from mid-morning through late afternoon. Aerometric values varied significantly over this period. In order to account for the effects on health associated with exposure to air pollutants and to humidity and temperature at the time of the testing, weighted averages had to be developed. In doing so the hour at which each panelist reported for testing was noted and the aerometric values for that hour were included in the weighted average for that day. This approach is expected to have been far more sensitive than using the maximum hourly average or an average of the hourly values over an arbitrary portion of the day.

The proportions of asthma panelists who reported discomfort symptoms are shown in Appendix I for each of the 40 days when symptom data were collected. The weighted averages of the air pollutants, relative humidity, and temperature are also given in Appendix I for each of the same days. The charts are provided to facilitate comparisons between the proportions of panelists who reported symptoms and the weighted averages of air pollution.

CORRELATION ANALYSIS

Pearson and two non-parametric correlation analyses were performed on the asthma panel data. The results are reported on the following pages.

TABLE 9B.   STATISTICAL PROFILE OF PULMONARY FUNCTION
    VARIABLE AND AGE AND HEIGHT OF PANELISTS MEASURED
            DURING ASTHMA PANEL SUREVEILLANCE

VARIABLE: MAXFEV = Maximum $FEV_{1.0}$ (in liters x 100)

MEAN	=	284.085	RANGE	=	480.000
VARIANCE	=	6,186.592	MINIMUM	=	59.000
KURTOSIS	=	0.422	MAXIMUM	=	539.000
STD DEV	=	78.655	VALID OBS	=	378
SKEWNESS	=	-0.345	MISSING OBS	=	1

VARIABLE: AGE - Age of panelist (in years)

MEAN	=	32.780	RANGE	=	27
VARIANCE	=	60.476	MINIMUM	=	22
KURTOSIS	=	-0.626	MAXIMUM	=	49
STD DEV	=	7.777	VALID OBS	=	40
SKEWNESS	=	0.704	MISSING OBS	=	1

VARIABLE: HEIGHT = Height of panelist (in inches)

MEAN	=	64.075	RANGE	=	11
VARIANCE	=	9.097	MINIMUM	=	58
KURTOSIS	=	-0.476	MAXIMUM	=	69
STD DEV	=	3.016	VALID OBS	=	41
SKEWNESS	=	-0.394	MISSING OBS	=	0

TABLE 9C. STATISTICAL PROFILE OF AIR POLLUTION
VARIABLES MEASURED DURING ASTHMA PANEL SURVEILLANCE

VARIABLE: OZONE = Estimate for oxide (in ppm)

MEAN	=	0.090	RANGE	=	0.290
VARIANCE	=	0.005	MINIMUM	=	0.010
KURTOSIS	=	0.242	MAXIMUM	=	0.300
STD DEV	=	0.069	VALID OBS	=	379
SKEWNESS	=	1.027	MISSING OBS	=	0

VARIABLE: CO = Carbon monoxide (in ppm/100)

MEAN	=	0.038	RANGE	=	0.060
VARIANCE	=	0.000	MINIMUM	=	0.020
KURTOSIS	=	-0.230	MAXIMUM	=	0.080
STD DEV	=	0.013	VALID OBS	=	378
SKEWNESS	=	0.536	MISSING OBS	=	1

VARIABLE: NO2 = Nitrogen dioxide (in ppm)

MEAN	=	0.077	RANGE	=	0.260
VARIANCE	=	0.002	MINIMUM	=	0.010
KURTOSIS	=	4.625	MAXIMUM	=	0.270
STD DEV	=	0.040	VALID OBS	=	353
SKEWNESS	=	1.510	MISSING OBS	=	26

VARIABLE: NO = Nitric oxide (in ppm)

MEAN	=	0.014	RANGE	=	0.050
VARIANCE	=	0.000	MINIMUM	=	0.010
KURTOSIS	=	10.601	MAXIMUM	=	0.060
STD DEV	=	0.008	VALID OBS	=	353
SKEWNESS	=	2.877	MISSING OBS	=	26

VARIABLE: HUMID = Humidity (in percent)

MEAN	=	62.164	RANGE	=	25.000
VARIANCE	=	82.264	MINIMUM	=	50.000
KURTOSIS	=	-1.086	MAXIMUM	=	75.000
STD DEV	=	9.070	VALID OBS	=	379
SKEWNESS	=	0.091	MISSING OBS	=	0

VARIABLE: TEMP = Temperature (in degrees Fahrenheit)

MEAN	=	74.211	RANGE	=	42.000
VARIANCE	=	89.305	MINIMUM	=	53.000
KURTOSIS	=	-0.698	MAXIMUM	=	95.000
STD DEV	=	9.450	VALID OBS	=	379
SKEWNESS	=	0.126	MISSING OBS	=	0

Pearson Correlation

The Pearson correlation coefficient (R) was used to measure the strength of relationship between two interval scale variables. R measures both the goodness of fit of a linear regression line and provides a test of a hypothesis of independence between two variables. The null hypothesis of interest is

$$H_o: \quad \rho = 0$$

where ρ is the population correlation coefficient. If two variables are linearly independent, then $\rho = 0$. Rejection of the null hypothesis leads to tentative acceptance of the alternative hypothesis of linear dependence between the two variables.

A test of this hypothesis in a bivariate normal population is given by the t-ratio, $t = R \left[(N-2)/(1-R^2)\right]^{\frac{1}{2}}$, with $N-2$ degrees of freedom. A two-tailed test of statistical significance was used.

The pearson correlation coefficients for the asthma panel are reported in Table 10. The significance levels are included at $\alpha = 0.01$, 0.05, and 0.10. A positive correlation indicates a direct relationship between the two variables, while a negative correlation indicates an inverse relationship. If a one-tailed test is preferred, merely interpret the levels of significance shown as $\alpha/2$ rather than α.

The relationship between MAXFEV and the air pollution variables was expected to be inverse; therefore, the correlation coefficients were expected to be negative. The estimated correlations are all of the wrong sign.

None of the coefficients for THROAT, CHEST, NAUSEA, OR OTHER are significantly different from zero. The coefficients for the variables BREATH and PHLEGM are significant only with respect to OZONE.

Air pollution variable NO is not significantly correlated with any of the discomfort symptoms. The variable HUMID is significantly negatively correlated with EYES, HEADACHE, HEADACHE EARLIER, and MAXFEV. HUMID is not significantly correlated with any of the other qualitative variables. The variable TEMP is significantly positively correlated with EYES, HEADACHE, HEADACHE EARLIER, and MAXFEV.

TABLE 10. PEARSON CORRELATION COEFFICIENTS FOR THE ASTHMA PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.25***	0.16***	0.16***	0.01	0.21***	0.21***
THROAT	-0.11	-0.02	-0.02	0.06	0.06	-0.02
CHEST	0.02	0.04	0.08	0.11	-0.03	0.04
HEADACHE	0.13**	0.18***	0.10*	-0.06	-0.15***	0.20***
NAUSEA	-0.04	-0.04	-0.01	-0.08	-0.07	0.04
OTHER	0.03	-0.01	0.03	-0.02	-0.06	0.01
HEADACHE EARLIER	-0.02	0.10**	0.09*	-0.01	-0.12**	0.15***
BREATH	0.11***	0.01	-0.01	0.04	-0.04	0.08
COUGH	-0.09*	-0.03	-0.02	0.07	0.01	-0.05
PHLEGM	0.15**	-0.03	0.04	-0.05	-0.04	0.11
MAXFEV	0.02	0.10**	0.13**	0.05	-0.08*	0.12**

*Significant at $\alpha = 0.10$

**Significant at $\alpha = 0.05$

***Significant at $\alpha = 0.01$

Out of all the discomfort symptom variables, EYES shows the most significant correlation with the air pollution variables. NO is the only air pollution variable which is not significantly correlated with EYES. Among the air pollution variables OZONE has more statistically significant positive coefficients than the others. The next most significant air pollution variables are CO, and NO_2, which are also significantly correlated with MAXFEV.

Correlation coefficients for the discomfort symptoms and air pollution variables are reported in Tables 10 and 11. Note that the correlation between HUMID and TEMP is -0.81 and is significant at $\alpha = 0.001$. This indicates possible collinearity between HUMID and TEMP. Note further, in Table 10, that the significant correlations for HUMID and TEMP and the discomfort symptoms are always opposite in sign and similar in magnitude. This analysis leads to the conclusion that HUMID and TEMP should not be included in any multiple regression specification at the same time.

Non-Parametric Correlations

Spearman's rank correlation coefficient (R_s) and Kendall's tau (τ) are both non-parametric; neither depends on a normal distribution. The Spearman's coefficient (R_s) is corrected for the occurrence of tied ranks. The significance of R_s can be determined by the same t-statistic used for the Pearson coefficient with R_s substituted for R. The Kendall's tau coefficient (τ) is also corrected for tied ranks. The significance of τ is determined by comparing τ to a normal distribution with a standard deviation equal to $[(4N + 10)/9N(N - 1)]^{\frac{1}{2}}$ where N is the number of observations.

The non-parametric correlation coefficients for the discomfort symptoms and the air pollution variables are reported in Tables 12 and 13. The results tend to confirm those derived from the Pearson correlation coefficients.

The qualitative variable EYES is the only symptom variable which is consistently significant with respect to the air pollution variables. The next most significantly correlated variable is HEADACHE. The qualitative variables THROAT, CHEST, NAUSEA, OTHER, HEADACHE EARLIER, and COUGH are not strongly correlated with air pollution variables OZONE, CO, and NO_2. Variable NO has stronger correlations than indicated by the Pearson correlations, but the coefficient with NAUSEA is of the negative sign. Negative correlation of discomfort symptoms with NO should be expected when the symptom variables show positive correlation with OZONE. NO is usually negatively correlated with OZONE. Table 11 shows such a relationship in this study.

TABLE 11. CORRELATION MATRIX OF AIR POLLUTION VARIABLES†

	OZONE	CO	NO2	NO	HUMID	TEMP
OZONE	1.0000 (0) S = 0.001	0.3921 (378) S = 0.001	0.0645 (353) S = 0.227	-0.2517 (353) S = 0.001	-0.4915 (379) S = 0.001	0.5608 (379) S = 0.001
CO	0.3921 (378) S = 0.001	1.0000 (0) S = 0.001	0.7216 (352) S = 0.001	0.2285 (352) S = 0.001	-0.1714 (378) S = 0.001	0.1983 (378) S = 0.001
NO2	0.0645 (353) S = 0.227	0.7216 (352) S = 0.001	1.0000 (0) S = 0.001	0.3822 (347) S = 0.001	-0.2026 (353) S = 0.001	0.1705 (353) S = 0.001
NO	-0.2517 (353) S = 0.001	0.2285 (352) S = 0.001	0.3822 (347) S = 0.001	1.0000 (0) S = 0.001	0.1206 (353) S = 0.023	-0.1839 (353) S = 0.001
HUMID	-0.4915 (379) S = 0.001	-0.1714 (378) S = 0.001	-0.2026 (353) S = 0.001	0.1206 (353) S = 0.023	1.0000 (0) S = 0.01	-0.8099 (379) S = 0.001
TEMP	0.5608 (379) S = 0.001	0.1983 (378) S = 0.001	0.1705 (353) S = 0.001	-0.1839 (353) S = 0.001	-0.8099 (379) S = 0.001	1.0000 (0) S = 0.001

†Number of cases is in parentheses; S = level of significance.

TABLE 12.   SPEARMAN CORRELATION COEFFICIENTS FOR THE ASTHMA PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.26***	0.15***	0.12***	0.06**	-0.21***	0.21***
THROAT	0.04	0.05	0.01	0.08*	-0.09***	0.11**
CHEST	0.01	0.03	0.01	0.12**	-0.04	0.05
HEADACHE	0.13***	0.18***	0.10**	-0.01	-0.15***	0.20***
NAUSEA	-0.04	-0.04	-0.01	-0.10**	-0.07*	0.03
OTHER	0.03	-0.92	-0.06	-0.04	-0.06	-0.01
HEADACHE EARLIER	-0.01	0.07*	0.06	0.01	-0.12***	0.14***
BREATH	0.12**	-0.12	-0.03	0.03	-0.04	0.08*
COUGH	-0.08*	-0.04	-0.05	0.09*	0.01	-0.06
PHLEGM	0.13**	-0.05	0.03	-0.07	-0.04	0.11*

*Significant at α = 0.10

**Significant at α = 0.05

***Significant at α = 0.01

TABLE 13. KENDALL CORRELATION COEFFICIENTS FOR THE ASTHMA PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.22***	0.13***	0.11***	0.06**	-0.20***	0.18***
THROAT	0.03	0.04	0.01	0.08*	-0.08**	0.09**
CHEST	0.01	0.02	0.01	0.11**	-0.03	0.04
HEADACHE	0.11***	0.16***	0.08**	-0.01	-0.14***	0.16***
NAUSEA	-0.03	-0.04	-0.01	-0.09**	-0.07*	0.02
OTHER	0.02	-0.02	-0.05	-0.04	-0.05	-0.01
HEADACHE EARLIER	-0.01	0.07*	0.05	0.01	-0.12***	0.12***
BREATH	0.10**	-0.02	-0.02	0.03	-0.04	0.06*
COUGH	-0.06*	-0.03	-0.04	0.08	0.01	-0.05
PHLEGM	0.11**	-0.05	0.03	-0.07	-0.04	0.09*

*Significant at α = 0.10
**Significant at α = 0.05
***Significant at α = 0.01

Summary of the Correlation Analysis

The only discomfort symptom which is consistently and sig-
nificantly correlated with the air pollution variables is EYES.
The only other qualitative variables which appear to be con-
nected with air pollution are HEADACHE and BREATH. MAXFEV does
not appear to be linearly related to the air pollution data for
the asthma panel.

The air pollution variable OZONE appears to be the most ex-
planatory. OZONE is positively correlated with EYES, HEADACHE,
BREATH, and PHLEGM. But the missing reports of PHLEGM lead to
skepticism in drawing any conclusion from the associated corre-
lation coefficients. The other air pollution variable which ex-
hibits significant correlation with some of the discomfort
symptoms is CO. NO does not appear to be strongly correlated
with any of the discomfort symptoms. Furthermore, NO_2 seems
only weakly correlated with the discomfort symptoms. Therefore,
NO and NO_2 are omitted in further analysis of the asthma panel.

Finally, the levels of humidity and temperature are highly
correlated with each other. And the correlations with the dis-
comfort symptoms indicate they have an effect which is opposite
in sign but equivalent from a statistical viewpoint. A multi-
variate analysis which uses several explanatory variables, like
multiple regression, should not use both humidity and tempera-
ture at the same time, since multicollinearity seems to exist
between the two explanatory variables. The distributions of
estimated regression parameters are quite sensitive to multi-
collinearity.

MEASURES OF ASSOCIATION BETWEEN VARIABLES

The following pages describe the associations found between
most of the variables included in this study. For example, the
association between MAXFEV and the air pollution variables and
the dependency of the discomfort symptoms on having a cold are
examined. In all, four measures of association are applied.

Simple Linear Regressions of $FEV_{1.0}$

Simple linear regression equations of the form

$$Y = a + bX$$

were computed with MAXFEV as the dependent variable and the air
pollution variables as the explanatory variables. The intercept
(a) and slope(b) were computed by ordinary least-squares re-
gression. The results are reported in Table 14.

TABLE 14. SIMPLE REGRESSION RESULTS WITH MAXFEV AS THE DEPENDENT VARIABLE

EXPLANATORY: OZONE

CORRELATION (R) = 0.02233	STD ERR OF EST = 78.73977
R SQUARED = 0.00050	INTERCEPT (a) = 281.80560
SIGNIFICANCE = 0.66514	SLOPE (b) = 25.44250

EXPLANATORY: CO

CORRELATION (R) = 0.10295	STD ERR OF EST = 78.22557
R SQUARED = 0.01060	INTERCEPT (a) = 260.41677
SIGNIFICANCE = 0.04577	SLOPE (b) = 625.38935

EXPLANATORY: NO2

CORRELATION (R) = 0.09306	STD ERR OF EST = 78.62108
R SQUARED = 0.00866	INTERCEPT (a) = 276.09287
SIGNIFICANCE = 0.08039	SLOPE (b) = 126.04091

EXPLANATORY: NO

CORRELATION (R) = 0.05480	STD ERR OF EST = 78.04043
R SQUARED = 0.00300	INTERCEPT (a) = 279.27642
SIGNIFICANCE = 0.30528	SLOPE (b) = 554.59520

EXPLANATORY: HUMID

CORRELATION (R) = -0.08631	STD ERR OF EST = 78.46550
R SQUARED = 0.00745	INTERCEPT (a) = 330.55249
SIGNIFICANCE = 0.09381	SLOPE (b) = -0.74750

EXPLANATORY: TEMP

CORRELATION (R) = 0.12223	STD ERR OF EST = 78.16886
R SQUARED = 0.01494	INTERCEPT (a) = 208.66602
SIGNIFICANCE = 0.01743	SLOPE (b) = 1.01616

The statistics which describe these simple regressions include the correlation coefficient (R) and the coefficient of determination (R^2), which measures the percentage of the variance of the dependent variable explained by regression. The test of a significant linear relationship between MAXFEV and the explanatory variable involves a two-tailed test that R is significantly different from zero. The level of significance (α) at which that hypothesis can be rejected is also reported in Table 14.

MAXFEV is not significantly linearly related to OZONE. MAXFEV is significantly related to CO at a level of significance greater than α = 0.05, but the sign of the slope term is not consistent with expectations. The results are probably spurious. The same can be said of the regression with NO_2 and NO as the explanatory variables.

No expectations of the signs of the slope coefficients of HUMID and TEMP were formulated. The regression with HUMID as the explanatory variable is significant at a level greater than α = 0.10. The sign of the estimated coefficient is negative, which indicates that MAXFEV is inversely related to the level of humidity. The largest coefficient of determination is provided with TEMP as the explanatory variable, and the estimated slope has positive sign and is significant at α = 0.017.

In summary, there are no strong inverse linear relationships between MAXFEV and the air pollution variables. Only the variables HUMID and TEMP yield results which are both reasonable in terms of sign and statistically signficant. Correlation analysis indicated that HUMID and TEMP are probably collinear. Inspection of scattergrams (reproduced in the Data Analysis Supplement) indicated no clear non-linear relationship between MAXFEV and any of the air pollution variables for the asthma panel taken as a whole.

Contingency Tables Between Discomfort Symptoms and Having a Cold

Asthma panelists were asked whether or not they experienced eye discomfort, throat discomfort, chest discomfort, headache, nausea, other discomfort (unspecified), headache earlier, shortness of breath, cough, and phlegm. The panelists were also asked asked whether or not they had a bad cold or were taking any medication on each day tested. It was expected that the response to to the discomfort symptom questions were dependent on the presence of a cold or taking medication.

In the following analysis of association between the symptom attributes and the cold attribute, the contingency tables tables are (2x2) and the degrees of freedom are (2-1)·(2-1) = 1. For one degree of freedom, the χ^2 value needed to reject a

hypothesis of independence at the $\alpha = 0.01$ level is 6.63. Rejection of the hypothesis of independence allows one to say that some statistical association exists between the two attributes. If the hypothesis is rejected, one may feel confident in concluding that the two attributes are in some way related. The χ^2 required to reject the hypothesis of indpendence at $\alpha = 0.05$ is $\chi^2 = 3.84$, and at $\alpha = 0.10$ is $\chi^2 = 2.70$. (The contingency tables are included in the Data Analysis Supplement.)

The computed χ^2 value for COLD and EYES is $\chi^2 = 2.35$, which is not large enough to reject the hypothesis of independence at the level of significance of $\alpha = 0.10$. Thus, there is no statistical evidence of dependence between eye discomfort and the presence of a bad cold for the asthma panel. The computed χ^2 value for COLD and THROAT is $\chi^2 = 22.02$, which is large enough to reject the hypothesis of independence at $\alpha = 0.01$. This leads to the tentative acceptance of the alternative hypothesis of dependence between COLD and THROAT. Throat discomfort seems to be dependent on the presence of a cold. The computed χ^2 value for COLD and CHEST is $\chi^2 = 0.81$, which is not large enough to reject the hypothesis of independence at $\alpha = 0.10$. The relationship between COLD and HEADACHE is indicated by a computed χ^2 of 3.61. This is large enough to reject the hypothesis of independence at $\alpha = 0.10$, but not at $\alpha = 0.05$. The relationship between COLD and NAUSEA is indicated by a computed χ^2 of 3.95. This is large enough to reject the hypothesis of independence at $\alpha = 0.05$, but not at $\alpha = 0.01$. The presence of headache or nausea and having a cold appears to be dependent, but that dependence is not strong. The computed χ^2 for COLD and OTHER is $\chi^2 = 7.53$, which is large enough to reject the hypothesis of independence at $\alpha = 0.01$. The presence of other discomfort and having a cold also appears to be dependent. The alternative hypothesis of dependence is supported between COLD and HEADACHE EARLIER. The computed χ^2 is 17.46, which is large enough to reject the hypothesis of indpendence at $\alpha = 0.01$. Thus, there is evidence of dependence between having a headache earlier in the day and having a cold. The computed χ^2 for COLD and BREATH is $\chi^2 = 1.58$, which is not large enough to reject the hypothesis of independence at $\alpha = 0.10$. Shortness of breath and having a cold appear to be independent for the asthma panel. The computed χ^2 for COLD and COUGH is $\chi^2 = 5.27$, which is enough to reject the hypothesis of independence at $\alpha = 0.05$, but not at $\alpha = 0.01$.

In summary, there is evidence of dependence between having a cold and throat discomfort, headache, nausea, other discomfort, headache earlier, or cough. There is not evidence of dependence between having a cold and eye discomfort, chest discomfort, or shortness of breath. One implication for further analysis is that the method should control for the presence of a cold when explaining the presence of the qualitative variables

by the air pollution variables. Otherwise, the investigator may falsely attribute the discomfort symptoms to some measure of air pollution.

Contingency Tables Between $FEV_{1.0}$ and Air Pollution Variables

A series of contingency tables were constructed between MAXFEV and the air pollution variables OZONE, CO, NO_2, and NO. MAXFEV was divided into two classes: $0 \leq MAXFEV < 300$ and $300 \leq MAXFEV$. OZONE was divided into two classes: $0 \leq OZONE < 0.1$ and $0.1 \leq OZONE$. Variable CO was divided into two classes: $0.01 \leq CO < 0.04$ and $0.04 \leq CO$. Variable NO_2 was divided into two classes: $0 \leq NO_2 < 0.04$ and $0.04 \leq NO_2$. Finally, NO was divided into two classes: $0 \leq NO < 0.02$ and $0.02 \leq NO$. All of the contingency tables are (2x2) and have one degree of freedom. The critical values for the χ^2 statistic are again $\chi^2 = 6.63$ at $\alpha = 0.01$, $\chi^2 = 3.84$ at $\alpha = 0.05$, and $\chi^2 = 2.70$ at $\alpha = 0.10$.

None of the computed χ^2 statistics are large enought to reject the hypothesis of independence at $\alpha = 0.01$ or $\alpha = 0.05$. The computed χ^2 between MAXFEV and CO is 3.17. The computed $\bar{\chi}^2$ between MAXFEV and NO is 2.97. These are greater than $\chi^2 = 2.70$; but not at $\alpha = 0.05$ nor at $\alpha = 0.01$.

In summary, there is not strong evidence of dependence between MAXFEV and air pollution for the asthma panel utilizing a chi-square test of independence. This analysis of dependence utilizing contingency tables tends to confirm the conclusions of the correlation analysis presented earlier.

Linear Probability Model

The form of a simple linear probability model is

$$Y_i = \alpha + \beta X_i + \epsilon_i$$

where

$$Y_i = \begin{cases} 1 \text{ if the symptom is present} \\ 0 \text{ if the symptom is not present} \end{cases}$$

X_i = the value of the explanatory variable (air monitoring data)

ϵ_i = an independently distributed random variable with zero mean

The regression equation may be interpreted as the probability that a symptom will be present given information about the value of the explanatory variable, OZONE, CO, NO_2, NO, HUMID, or TEMP. The slope of the regression line, β, measures the effect on the probability given a unit change in the explanatory variable.

Examination of the probability of the error term indicates certain properties of the model. The error has zero mean, but the variance of the error is not constant for all observations. The presence of heteroscedasticity results in a loss of efficiency, but does not in itself result in biased or inconsistent parameter estimates. However, the standard tests of significance must be interpreted with caution.

Simple linear probability regressions using eye discomfort as the dependent variable are in Table 15. It is noted that low R^2 values are not unusual for regressions using a dichotomous dependent variable. There appears to be a very definite relationship between the probability of eye discomfort and the air pollution variables except for NO.

Note that the regressions using HUMID and TEMP as the explanatory variables have estimated slope coefficients which are equal in magnitude, but opposite in sign. This was expected given the collinearity indicated from the correlation analysis. This pattern is repeated for all the dependent variables. The variable TEMP appears to be better in most cases from the standpoint of explanatory power as indicated by the R-squares and the level of significance.

The linear probability regression for the remaining discomfort symptom variables are not so impressive. Only those which were statistically significant at $\alpha = 0.05$ or better are presented in Table 16.

None of the regressions for NAUSEA, OTHER and COUGH are significant. The variable PHLEGM was not tested because of the small number of observations. Moreover, the variable HEADACHE EARLIER was excluded because there seemed to be no direct cause relationship between that variable and the levels of the air pollution at times the asthma panelists reported for daily surveillance.

In summary, only two of the discomfort symptoms variables show any statistical dependence on the air pollution variables. These symptoms are eye discomfort and headache. With EYES as the dependent variable, the significant regressions are:

Prob (EYES) = 0.183 + 1.725(OZONE) $R^2 = 0.063$

Prob (EYES) = 0.111 + 5.940(CO) $R^2 = 0.026$

TABLE 15. SIMPLE LINEAR PROBABILITY REGRESSIONS WITH EYE DISCOMFORT AS THE DEPENDENT VARIABLE

EXPLANATORY: OZONE**

CORRELATION (R)	=	0.25120	INTERCEPT (a)	=	0.18330
R SQUARED	=	0.06310	SLOPE (b)	=	1.72504
SIGNIFICANCE	=	0.00001	PLOTTED VALUES	=	379
STD ERR OF EST	=	0.45898			

EXPLANATORY: CO**

CORRELATION (R)	=	0.16185	INTERCEPT (a)	=	0.11092
R SQUARED	=	0.02620	SLOPE (b)	=	5.94007
SIGNIFICANCE	=	0.00159	PLOTTED VALUES	=	378
STD ERR OF EST	=	0.46824			

EXPLANATORY: NO2 **

CORRELATION (R)	=	0.14593	INTERCEPT (a)	=	0.23978
R SQUARED	=	0.02130	SLOPE (b)	=	5.94007
SIGNIFICANCE	=	0.00588	PLOTTED VALUES	=	355
STD ERR OF EST	=	0.46833			

EXPLANATORY: NO

CORRELATION (R)	=	0.01196	INTERCEPT (a)	=	0.32399
R SQUARED	=	0.00014	SLOPE (b)	=	0.73372
SIGNIFICANCE	=	0.82276	PLOTTED VALUES	=	353
STD ERR OF EST	=	0.47305			

EXPLANATORY: HUMID**

CORRELATION (R)	=	-0.20567	INTERCEPT (a)	=	1.00531
R SQUARED	=	0.04230	SLOPE (b)	=	-0.01074
SIGNIFICANCE	=	0.00006	PLOTTED VALUES	=	379
STD ERR OF EST	=	0.46405			

EXPLANATORY: TEMP**

CORRELATION (R)	=	0.21398	INTERCEPT (a)	=	-0.45804
R SQUARED	=	0.04579	SLOPE (b)	=	0.01072
SIGNIFICANCE	=	0.00003	PLOTTED VALUES	=	379
STD ERR OF EST	=	0.46321			

**Significant at $\alpha = 0.05$

TABLE 16. SIGNIFICANT LINEAR PROBABILITY REGRESSIONS
FOR THE ASTHMA PANEL

DEPENDENT: THROAT
EXPLANATORY: TEMP

CORRELATION (R)	=	0.10691	INTERCEPT (a)	=	-0.06905
R SQUARED	=	0.01143	SLOPE (b)	=	0.00530
SIGNIFICANCE	=	0.03749	PLOTTED VALUES	=	379
STD ERR OF EST	=	0.46675			

DEPENDENT: CHEST
EXPLANATORY: NO

CORRELATION (R)	=	0.11174	INTERCEPT (a)	=	0.30238
R SQUARED	=	0.01249	SLOPE (b)	=	7.12290
SIGNIFICANCE	=	0.03586	PLOTTED VALUES	=	353
STD ERR OF EST	=	0.48867			

DEPENDENT: HEADACHE
EXPLANATORY: OZONE

CORRELATION (R)	=	0.12964	INTERCEPT (a)	=	0.14930
R SQUARED	=	0.01681	SLOPE (b)	=	0.77853
SIGNIFICANCE	=	0.01153	PLOTTED VALUES	=	379
STD ERR OF EST	=	0.41116			

DEPENDENT: HEADACHE
EXPLANATORY: CO

CORRELATION (R)	=	0.17759	INTERCEPT (a)	=	0.00102
R SQUARED	=	0.03154	SLOPE (b)	=	5.70141
SIGNIFICANCE	=	0.00052	PLOTTED VALUES	=	378
STD ERR OF EST	=	0.40846			

DEPENDENT: HEADACHE
EXPLANATORY: HUMID

CORRELATION (R)	=	-0.15254	INTERCEPT (a)	=	0.65196
R SQUARED	=	0.02327	SLOPE (b)	=	-0.00696
SIGNIFICANCE	=	0.00291	PLOTTED VALUES	=	379
STD ERR OF EST	=	0.40981			

DEPENDENT: HEADACHE
EXPLANATORY: TEMP

CORRELATION (R)	=	0.19772	INTERCEPT (a)	=	-0.42399
R SQUARED	=	0.03909	SLOPE (b)	=	0.00866
SIGNIFICANCE	=	0.00011	PLOTTED VALUES	=	379
STD ERR OF EST	=	0.40648			

DEPENDENT: BREATH
EXPLANATORY: OZONE

CORRELATION (R)	=	0.10600	INTERCEPT (a)	=	0.25252
R SQUARED	=	0.01124	SLOPE (b)	=	0.71598
SIGNIFICANCE	=	0.03915	PLOTTED VALUES	=	379
STD ERR OF EST	=	0.46376			

$$\text{Prob(EYES)} \quad = \quad 0.240 + 1.187(NO_2) \qquad R^2 = 0.021$$

$$\text{Prob(EYES)} \quad = \quad 1.005 - 0.011(HUMID) \quad R^2 = 0.042$$

$$\text{Prob(EYES)} \quad = \quad -0.458 + 0.011(TEMP) \quad R^2 = 0.046$$

The significant regressions with HEADACHE as the dependent variables are:

$$\text{Prob(HEADACHE)} \quad = \quad 0.652 - 0.007(HUMID) \quad R^2 = 0.023$$

$$\text{Prob(HEADACHE)} \quad = \quad -0.424 + 0.009(TEMP) \quad R^2 = 0.039$$

Thus, eye discomfort is seemingly dependent on the presence of ozone, carbon monoxide, nitrogen dioxide, humidity, or temperature. The dependency of the headache is on humidity or temperature. These results are not surprising considering the outcome of the correlation analysis presented earlier.

SELECTED MULTIVARIATE LINEAR PROBABILITY REGRESSIONS

The form of a multivariate linear probability model is

$$\theta_i = \text{Prob}(Y_i = 1) = \beta_o + \sum_{j=1}^{k} \beta_j X_{ij}; \qquad i = 1,\ldots,N$$

The interpretation is the same as the simple linear probability model. The only difference is that there are several explanatory variables. The predicted value of the dependent variable can be interpreted as the probability that the qualitative characteristic, discomfort, is present given values of the explanatory variables. Only two of the discomfort symptoms, EYES and HEADACHE, were chosen for this analysis, because they showed sensitivity to the air pollution variables in the correlation analysis.

The correlation analysis indicated that OZONE and CO were the most explanatory of the air pollution variables. Variable TEMP was included as an environmental control, and HUMID was not included in order to avoid multi-collinearity. Binary variable COLD was included because the chi-square tests indicated dependence between having a cold and reporting certain discomfort symptoms. Differences between individuals required the inclusion of AGE as a control variable. The results are reported in Table 17.

TABLE 17.   MULTIVARIATE LINEAR PROBABILITY FUNCTIONS FOR EYE
DISCOMFORT AND HEADACHE--ALL ASTHMA PANELISTS
(STANDARD ERRORS IN PARENTHESES)

Prob(EYE)   =   -0.390 + 1.138(OZONE)** + 2.707(CO)   + 0.006(TEMP)**

                              (0.445)   (2.045)   (0.003)

                            + 0.297(COLD)**   + 0.002(AGE)

                              (0.109)   (0.003)

        . R^2 = 0.09, N = 368, F = 7.36

Prob(HEADACHE) =   -0.717 - 0.261(OZONE)   + 5.299(CO)** + 0.009(TEMP)**

                              (0.393)   (1.809)

                            + 0.290(COLD)**   + 0.002(AGE)

                              (0.096)   (0.003)

        R^2 = 0.08, N = 368, F = 6.24

**Significant at α = 0.05

The F-statistic for the eye discomfort function is F = 7.36 which is significant at α = 0.01 indicating a rejection of a null hypothesis that all coefficients are simultaneously zero. The R^2 = 0.09 indicates that 9 percent of the variation of this dependent variable is explained by regression. Air pollution variable OZONE and environmental variable TEMP have a significant direct relationship with eye discomfort. The coefficient for variable CO is not significantly different from zero at α = 0.05.

The F-statistic for the headache function is also significant at α = 0.01. The R^2 = 0.08 indicates 8 percent of the variation in this qualitative variable is explained by regression. Air pollution variable OZONE is not significantly related to the dependent variable HEADACHE. The variables CO and TEMP exhibit a significant positive relationship in predicting the probability of the headache discomfort symptom.

In both regressions, COLD has a positive coefficient which is statistically significant. Also in both regressions, the coefficient of the variable AGE is not significantly different from from zero.

Two linear probability specifications were estimated for an asthma panel subset not having a cold. Variable AGE was dropped because it was not significantly different from zero in the previous specifications. Variable NO_2 was added as an explanatory variable. The dependent variables were again EYES and HEADACHE. The results are reported in Table 18.

The estimated coefficients were tested for significant at α = 0.05. The estimated coefficient for OZONE is significantly positive with EYES as the dependent variable, but the OZONE coefficient is not significant with HEADACHE as the dependent variable. Variable CO is not significant with EYES as the dependent variable; however, CO is significant with HEADACHE as the dependent variable. Variable NO_2 is not significant in either specification. TEMP is significant only with HEADACHE as the dependent variable.

Comparison of the regression results between all asthma panelists and the subset not having a cold leads to the conclusion that the results are similar. Both sets of regressions have estimated coefficients which are similar in magnitude, have the same sign, and remain either significant or not significant. That is, the slope coefficients did not change drastically when the sample was restricted to asthma panelists not having a cold. Of course, this conclusion might change if a non-linear specification for the probability function were utilized.

TABLE 18.   MULTIVARIATE LINEAR PROBABILITY FUNCTIONS
FOR EYE DISCOMFORT AND HEADACHE--ASTHMA PANELISTS
WITHOUT A COLD
(STANDARD ERRORS IN PARENTHESES)

Prob(EYES)   =   -0.249 + 1.040(OZONE)** + 2.523(CO)

                            (0.452)   (2.462)

                        + 0.670(NO2)   + 0.004(TEMP)

                            (0.503)   (0.003)

R^2 = 0.08, N = 335, F = 6.83

Prob(HEADACHE) =   -0.574 - 0.299(OZONE)   + 5.413(CO)**

                            (0.399)   (2.170)

                        - 0.547(NO2)   + 0.009(TEMP)**

                            (0.401)   (0.004)

R^2 = 0.05, N = 335, F = 4.47

**Significant at α = 0.05

BETWEEN GROUP DIFFERENCES

Two possibilities which could affect usefulness of the asthma panel results are considered in the following material:

1. That there were differences in sensitivity to air pollution between asthma panelists having and those not having a cold.

2. That there were differences between one or more of the sub-panels which would not permit certain data to be aggregated.

Sensitivity Analysis for Asthma Panelists Having and Not Having a Cold

The asthma panel was divided into two mutually exclusive subsets, those panelists who reported having a cold and those who reported not having a cold. This was done to see if there was any difference in the sensitivity to air pollution between these two groups.

The subset of panelists having a cold was examined first. Pearson correlation coefficients were computed between each of the air pollution variables and the discomfort symptoms variables along with MAXFEV.

Two primary differences were found between these correlations and the correlations for the asthma panel as a whole. First, the correlations are generally larger than before. However, most are not statistically significant. If the panelists having a cold are generally more responsive to air pollution, the data are not strongly supportive. Second, the correlation coefficients between COUGH and the air pollution variables OZONE, CO, and NO_2 are now quite large in magnitude and statistically significant at the $\alpha = 0.05$ level. But the correlations are negative.

Non-parametric correlations, the Spearman and Kendall coefficients, were also computed. The non-parametric correlations support the Pearson correlations. Again, the coefficients are generally larger than those computed for the asthma panel as a whole, and the cough variable is significantly negatively correlated with OZONE, CO, and NO_2.

To examine the MAXFEV performance of the subset having a cold, scattergrams were plotted and linear regressions for MAXFEV with the air pollution variables as explanatory were computed. None of the regressions were statistically significant. The scattergrams did not exhibit any obvious non-linear relationship. Therefore, the resulting statistics are not

reported here. The implication of the analysis is that MAXFEV shows no significant systematic relationship with the air pollution variables for the subset having a cold.

Simple linear probability regressions were run with the discomfort symptoms as the dependent variables. Only those regressions having a level of significance of $\alpha = 0.10$ or greater are reported. Those regressions significant only with HUMID or TEMP are not reported.

The only discomfort symptoms that are significantly related to the air pollution variables for this subset were eye discomfort and headache. The estimates are:

$$\text{Prob(EYES)} \quad = \quad 0.255 + 4.684(\text{OZONE}) \quad R^2 = 0.17$$

$$\text{Prob(EYES)} \quad = \quad -0.031 + 8.904(\text{NO}_2) \quad R^2 = 0.21$$

$$\text{Prob(HEADACHE)} \quad = \quad 0.093 + 5.664(\text{OZONE}) \quad R^2 = 0.25$$

$$\text{Prob(HEADACHE)} \quad = \quad -0.416 + 24.838(\text{CO}) \quad R^2 = 0.45$$

$$\text{Prob(HEADACHE)} \quad = \quad -0.457 + 14.015(\text{NO}_2) \quad R^2 = 0.54$$

Comparison with the linear probability regressions for the asthma panel as a whole leads to the observation that the coefficients of determination are much higher--a larger percentage of the dependent variable is explained for the restricted sample. Moreover, the estimated slope coefficients are much larger in magnitude. The implication is that the panelists having a cold are more sensitive to OZONE and NO_2 in experiencing eye discomfort and are more sensitive to OZONE, CO, and NO_2 in experiencing a headache than the whole panel.

The linear probability specification was applied separately to the panelists who did not report a cold. The regressions, with EYES as the dependent variable, significant at $\alpha = 0.05$ or better are:

$$\text{Prob(EYES)} \quad = \quad 0.168 + 1.751(\text{OZONE}) \quad R^2 = 0.067$$

$$\text{Prob(EYES)} \quad = \quad 0.069 + 6.719(\text{CO}) \quad R^2 = 0.034$$

$$\text{Prob(EYES)} \quad = \quad 0.229 + 1.167(\text{NO}_2) \quad R^2 = 0.022$$

$$\text{Prob(EYES)} \quad = \quad -1.010 + 0.011(\text{HUMID}) \quad R^2 = 0.046$$

$$\text{Prob(EYES)} \quad = \quad -0.470 + 0.011(\text{TEMP}) \quad R^2 = 0.046$$

These estimates are almost identical to those computed for the whole panel.

The significant estimates with HEADACHE as the dependent variable are:

$$Prob(HEADACHE) = 0.139 + 0.759(OZONE) \quad R^2 = 0.017$$

$$Prob(HEADACHE) = 0.016 + 5.011(CO) \quad R^2 = 0.025$$

$$Prob(HEADACHE) = 0.670 - 0.007(HUMID) \quad R^2 = 0.028$$

$$Prob(HEADACHE) = 0.451 + 0.009(TEMP) \quad R^2 = 0.042$$

The regressions with explanatory variables HUMID and TEMP are almost identical to those estimated for the whole panel. However, the regressions with OZONE and CO as the explanatory variables are now significant at $\alpha = 0.05$, but were not significant for the whole panel.

The remaining significant linear probability regressions for the subset not having a cold are:

$$Prob(CHEST) = 0.292 + 7.415(NO) \quad R^2 = 0.014$$

$$Prob(THROAT) = 0.209 + 6.529(NO) \quad R^2 = 0.012$$

$$Prob(THROAT) = 0.662 - 0.006(HUMID) \quad R^2 = 0.022$$

$$Prob(THROAT) = 0.236 + 0.797(OZONE) \quad R^2 = 0.014$$

None of these specifications were significant for the whole panel but they are for the subset not having a cold. The variable NO becomes a significant explanatory variable in predicting the probability of experiencing chest or throat discomfort when the panelist does not have a cold. Variable OZONE is a significant predictor of the probability of shortness of breath for those in the subset not having a cold. In general, the foregoing analysis emphasizes the need to control for the presence of a cold.

Differences Between Sub-Panels

The asthma panel was divided into four sub-panels for daily surveillance. These groups were tested for four successive two-week periods. Differences between the sub-panels is a potential source of variation which must be examined. The following

paragraphs present the results of difference in means tests and two-way analysis of variance (ANOVA) for the four groups. The difference in MAXFEV between sub-panels was examined. Table 19 gives the sample size, sample mean, and sample standard deviation of MAXFEV for the four groups.

TABLE 19.   SAMPLE MEANS AND STANDARD DEVIATIONS
FOR MAXFEV OF THE FOUR ASTHMA SUB-PANELS
(NO RESTRICTIONS ON TOTAL SAMPLE)

Sub-Panel	N	$\overline{X}$	S
1	126	302.47	61.9
2	112	281.19	85.7
3	91	298.81	107.0
4	50	230.56	68.6

An F-test of sample variances was performed between pairs of all four sub-panels. This was necessary to choose the appropriate t-test to test for differences in means between all four groups. The null hypothesis to be tested first is

$$H_O: \quad \sigma_i^2 = \sigma_j^2, \text{ with the alternative } H_A: \quad \sigma_i^2 \neq \sigma_j^2, \text{ where}$$

$i, j = 1,\ldots,4$ with $i \neq j$. From the sample variances F is computed as $F = $ larger S^2/smaller S^2. If the probability for F is greater than some chosen level of significance (α), H_O is accepted. If the null hypothesis is rejected, then an approximation to t must be made which is based on the separate variance estimate.

The results of the F-tests are given in Table 20. The level of significance chosen was $\alpha = 0.10$. A two-tailed test of significance was applied. The results indicate a rejection of the hypothesis of equal variance between all of the sub-panels except one. Therefore, there is evidence that the population variances of MAXFEV between sub-panels are not equal when there are no restrictions placed on the selection of observations other than the sub-panel classification.

Given populations with unequal variances, an approximation to the t for the difference in sample means should be applied. The results are given in Table 21. The null hypothesis is $H_O: \quad \mu_i = \mu_j$ for all $i \neq j$, and the alternative hypothesis is

TABLE 20. DIFFERENCE IN VARIANCES TEST ON ASTHMA SUB-PANELS
(NO RESTRICTIONS ON TOTAL SAMPLE)

H_o	F	$\alpha/2$	Significant at $\alpha = 0.10$	Decision on H_o
$\sigma_1 = \sigma_2$	1.91	0.00	yes	reject
$\sigma_1 = \sigma_3$	2.99	0.00	yes	reject
$\sigma_1 = \sigma_4$	1.23	0.18	no	do not reject
$\sigma_2 = \sigma_3$	1.56	0.02	yes	reject
$\sigma_2 = \sigma_4$	1.56	0.04	Yes	reject
$\sigma_3 = \sigma_4$	2.44	0.00	yes	reject

TABLE 21. DIFFERENCE IN MAXFEV MEANS TEST ON ASTHMA
SUB-PANELS USING SEPARATE VARIANCE ESTIMATES

H_o	t	$\alpha/2$	Significant at $\alpha = 0.05$	Decision on H_o
$\mu_1 = \mu_2$	2.17	0.015	no	do not reject
$\mu_1 = \mu_3$	0.32	0.376	no	do not reject
$\mu_1 = \mu_4$	6.45	0.000	yes	reject
$\mu_2 = \mu_3$	-1.27	0.102	no	do not reject
$\mu_2 = \mu_4$	4.01	0.000	yes	reject
$\mu_3 = \mu_4$	4.60	0.000	yes	reject

H_A: $\mu_i \neq \mu_j$. The level of significance chosen was $\alpha = 0.05$ (0.025 in each trial) using the two-tailed test.

The results in the difference in means test are mixed. While mean MAXFEV for Sub-Panel 4 is significantly different from the mean MAXFEVs of Sub-Panels 1, 2, and 3, the mean MAXFEVs between Sub-Panels 1, 2, and 3 are not significantly different from each other. This indicated difference for Sub-Panel 4 may be due to the small sample size of 50, about half the size of each of the other groups. Sub-Panel 4 represented 13.2 percent of the total asthma panel.

Differences Between Sub-Panels with MAXFEV Adjusted for Age and Height

A potential source of between group differences is age and height of each panelist. This is particularly true if a given sub-panel has a small sample size as does Sub-Panel 4. The hypothesis to be tested is that the between group differences in MAXFEV are due to age and height.

To test this hypothesis, the difference between the recorded MAXFEV and predicted $FEV_{1.0}$ was computed from a linear equation with age and height as the explanatory variables. Furthermore, the sample was restricted to panelists not having a cold. The estimated equation is:

$$\text{Predicted } FEV_{1.0} = 13.902 - 3.203(\text{AGE}) + 5.911(\text{HEIGHT})$$

$$(0.484) \qquad (1.271)$$

The coefficient of determination for this equation was $R^2 = 0.20$. The standard error of each coefficient is in parentheses below the coefficient. Twenty percent of the variation in MAXFEV is accounted for by age and height. Each of the estimated slope coefficients is significantly different from zero at $\alpha = 0.10$ level of significance.

Again, a test of a hypothesis of no differences between variances of the MAXFEV difference variable between groups is appropriate. The results are given in Table 22. Only the variance of Sub-Panel 4 appears to be different at $\alpha = 0.10$ level of significance.

A pooled variance estimate was used to compute the t-statistic to test for differences in sub-panel means of MAXFEV difference variable, since the hypothesis of unequal variances could not be rejected between all sub-panels. The results are given in Table 23. Only the hypothesis that $\mu_1 = \mu_4$ and $\mu_2 = \mu_4$ can be rejected. Again, Sub-Panel 4 seems to be the only sub-panel which is different from the rest. And much of the unexplained variation apart from age and height contained in

TABLE 22. DIFFERENCE IN VARIANCES TEST ON ASTHMA SUB-PANELS: DIFFERENCE IN MAXFEV FOR PANELISTS NOT HAVING A COLD

H_o	F	$\alpha/2$	Significant at $\alpha = 0.10$	Decision on H_o
$\sigma_1 = \sigma_2$	1.03	0.45	no	do not reject
$\sigma_1 = \sigma_3$	1.25	0.13	no	do not reject
$\sigma_1 = \sigma_4$	2.20	0.01	yes	reject
$\sigma_2 = \sigma_3$	1.22	0.17	no	do not reject
$\sigma_2 = \sigma_4$	2.25	0.01	yes	reject
$\sigma_3 = \sigma_4$	2.74	0.00	yes	reject

TABLE 23. DIFFERENCE IN MEANS TEST ON ASTHMA SUB-PANELS: DIFFERENCE IN MAXFEV FOR PANELISTS NOT HAVING A COLD

H_o	t	$\alpha/2$	Significant at $\alpha = 0.05$	Decision on H_o
$\mu_1 = \mu_2$	0.34	0.366	no	do not reject
$\mu_1 = \mu_3$	1.47	0.072	no	do not reject
$\mu_1 = \mu_4$	3.32	0.001	yes	reject
$\mu_2 = \mu_3$	1.10	0.137	no	do not reject
$\mu_2 = \mu_4$	2.97	0.002	yes	reject
$\mu_3 = \mu_4$	1.78	0.039	no	do not reject

Sub-Panel 4 could easily be caused by differences in other variables, such as humidity or temperature, which are not panelist characteristics.

Analysis of Variance Between Sub-Panels

The model applied was a fixed effects model in a two-way analysis. It was assumed that the observed MAXFEV is a sum of systematic effects associated with experimental treatments, plus random error.

A two-way ANOVA with MAXFEV as the dependent variable was performed for the panelists who reported not having a cold. Again, the main concern was whether or not the sub-panels which were tested on different weeks are significantly different from each other. Therefore, in every ANOVA performed, the sub-panel was used as a treatment (explanatory) variable. A total of six ANOVA were performed. The first three used OZONE, CO, and TEMP, respectively, as the other treatment variable. The second three used the same air pollution variables; however, Sub-Panel 4 was excluded from the analysis. The reason for the exclusion was that the difference in means tests performed above indicated that Sub-Panel 4 may be distinct. The hypothesis to be tested is that Sub-Panel 4 is the distinct group.

OZONE was divided into three ranges which were chosen to equal plus or minus one standard deviation from the mean. Likewise, CO and TEMP were divided the same way. The reason for categorizing these explanatory variables was that extreme variation in any of them was expected to affect MAXFEV. The results of the ANOVA with MAXFEV as the dependent variable and with sub-panels and either OZONE, CO, or TEMP as treatment variables showed that for the interaction between OZONE and the sub-panels, the F-ratio is not significant at $\alpha = 0.05$, but it is significant at $\alpha = 0.10$. This indicates that there may have been some interaction between OZONE and the sub-panels, but the evidence is not strong. The other effect of primary interest is that of the sub-panel variable itself. The sub-panel variable has an F-ratio that is significant at $\alpha = 0.01$ at the same time, the OZONE variable has an F-ratio that is not significant. The interaction variable for CO and the sub-panels is not significant. Again, the sub-panel variable is significant, while the CO variable is not. A third ANOVA indicates no significant interaction between the sub-panels and TEMP in explaining the variation in MAXFEV. The sub-panel variable by itself has an F-ratio which is significant, while the F-ratio for TEMP is not. All three ANOVA indicate that there is a significant difference between sub-panels in explaining the variation in MAXFEV which has not been adjusted for differences in age and height of the study subjects.

The second set of three ANOVA excludes Sub-Panel 4 from the analysis. The implications of the results are quite different. In all three cases the interaction term has F-ratios which are not significant. The F-ratios for the variables OZONE, CO, and TEMP are also not significant. The primary difference between these ANOVA which exclude Sub-Panel 4 and the first set of ANOVA lies in the F-ratios for the group variable. The F-ratio for sub-panel is not significant at $\alpha = 0.05$ for all three ANOVA. However, the F-ratio for the sub-panel variable is significant at $\alpha = 0.10$ in two of the ANOVA, one using OZONE and the other using TEMP. The implication is that the between group variation evident in the first set of ANOVA is absent in the second set of ANOVA where Sub-Panel 4 is excluded.

The implications of the second set of ANOVA above is consistent with the previous tests for differences in MAXFEV between groups. Sub-Panel 4 appears to be distinct from the other three. Based on these results, Sub-Panel 4 is dropped from further analysis except where between group differences can be identified and controlled.

ANOVA with MAXFEV Adjusted for Age and Height

The six ANOVA above were replicated with the MAXFEV difference variable. The MAXFEV difference variable was actual MAXFEV minus predicted $FEV_{1.0}$ where predicted $FEV_{1.0}$ was computed from variables. The interaction term in all cases was not statistically significant.

The group effect term is statistically significant by the F-ratio for all three ANOVA which included all sub-panels. But the group effect term is not statistically significant for the three ANOVA when Sub-Panel 4 is excluded. The implication is that Sub-Panel 4 remains distinct from the other three sub-panels after attempting to control for the age and height differences.

Summary of the Between Group Analysis

There is no logical nor theoretical reason why any of the sub-panels should be distinct or different from each other. The temporal difference in the sub-panels should not, in itself, create differences between the groups. However, differences between the sub-panels in their measured reactions to the air pollution variables could exist. This is because of the possible differences in the environment at the time of measurement and of differences in the composition of the sub-panels due to small sample or self-selection bias.

The reason, then, for this analysis was to determine if there is any difference between the sub-samples which cannot be controlled using appropriate statistical methods. If there is no difference that cannot be controlled statistically, then the sub-panels may be analyzed simultaneously as a pooled sample r representative of the population from which the sample was drawn.

Different methods indicate that there is a difference between the four groups. These same methods indicate that Sub-Panels 1, 2, and 3 are not different from each other. And the methods identify Sub-Panel 4 as a distinct group. When MAXFEV was adjusted for age and height, the conclusions remained essentially unaltered. This does not mean that there is no logical reason for the difference. For example, examination of the proportions of panelists reporting discomfort symptoms reveals a noticeable decrease in those proportions on the Sub-Panel 4 test dates. Moreover, variation in the level of carbon monoxide on those same test dates is noticeably absent. In addition, the level of relative humidity was higher and the temperature was lower on the test dates for Sub-Panel 4.

The reason why Sub-Panel 4 seems distinct remains unidentified. A conservative approach, therefore, is to exclude Sub-Panel 4 from further analysis as a possible source of contamination. The evidence is strong in favor of treating the other three sub-panels as representative of the population from which they were drawn.

DISCOMFORT SYMPTOMS ANALYZED BY DATE OF MEASUREMENT

The asthma panel was interviewed on 40 different dates. The sample was divided into four sub-panels. The first sub-panel was tested on ten consecutive days, excluding the weekend. The second, third, and fourth sub-panels were tested over successive ten-day periods, also excluding weekends. The dates were recorded as dates 1 through 40.

On each date, the proportion of the panelists reporting discomfort with respect to each of the qualitative symptoms was calculated. The number of subjects tested on each date ranged from 4 to 13. For dates 1 through 30, i.e., during daily surveillance of the first three sub-panels, the lowest number of panelists tested was eight.

The average and maximum levels of OZONE, CO, NO_2, NO, HUMID, and TEMP were computed for each date also. The average and maximum levels of air pollution variables were then related to the proportion of panelists reporting each discomfort symptom on each date.

Analysis of Eye Discomfort Using Proportions of Panelists Reporting

The LOGIT specification consolidates observations of the dependent and explanatory variables as follows. Let f_g denote the proportion of panelists reporting a discomfort symptom for date $g = 1,\ldots,G$. Let $\bar{X}_g$ denote the average level of an air pollution variable on date g. Then the LOGIT is:

$$\ln[f_g/(1 - f_g)] = \beta_0 + \beta_1\bar{X}_g; \quad g = 1,\ldots,G,$$

with G denoting the number of classes. This grouping technique tends to reduce the degrees of freedom, and the detail in the original data will be muted. Aggregation and regression toward the mean will increase the coefficient of determination. And, the LOGIT specification exhibits heteroscedasticity due to the unequal size of the sub-panels. However, the functional form is logically consistent with the probability interpretation. The alternative is maximum likelihood estimation of the logistic function directly from the micro data, a much more expensive procedure.

A linear probability specification using the proportions of panelists reporting is:

$$f_g = \alpha_0 + \alpha_1\bar{X}_g; \quad g = 1,\ldots,G.$$

This linear specification of the probability (proportion) is inconsistent with the probability interpretation, but it may lead to close approximations within the range of the original data. Extrapolation beyond the range of the data is particularly dangerous when using the linear form.

The qualitative variable, EYES, was chosen for analysis since it seemed more responsive than the others. The regressions using the linear form with the proportion of panelists reporting as the dependent variable and average of OZONE, CO, NO$_2$, and TEMP as the dependent variables with Sub-Panel 4 excluded are:

$$\theta = 0.213 + 1.758(OZONE)*** \quad R^2 = 0.22$$

$$\theta = 0.300 + 2.014(CO) \quad R^2 = 0.06$$

$$\theta = 0.105 + 3.300(NO_2)*** \quad R^2 = 0.49$$

$$\theta = 0.132 + 0.003(TEMP) \quad R^2 = 0.02$$

where θ denotes the estimated probability of eye discomfort and *** indicates significance at $\alpha = 0.01$. Both OZONE and NO$_2$ are

significant predictors of eye discomfort, while CO and TEMP are not.

The LOGIT regressions with Sub-Panel 4 excluded are:

$$\ln\left(\frac{\theta}{1-\theta}\right) = -1.360 + 8.695(OZONE)*** \quad R^2 = 0.23$$

$$\ln\left(\frac{\theta}{1-\theta}\right) = -0.954 + 10.478(CO)** \quad R^2 = 0.06$$

$$\ln\left(\frac{\theta}{1-\theta}\right) = -1.867 + 15.970(NO_2)*** \quad R^2 = 0.70$$

$$\ln\left(\frac{\theta}{1-\theta}\right) = -1.002 + 0.020 (TEMP) \quad R^2 = 0.03$$

Here, *** indicates significance at $\alpha = 0.01$ and ** indicates significance at $\alpha = 0.05$. In both the linear case and the LOGIT, these tests of significance should be interpreted with caution because of the heteroscedasticity casued by unequal size-panels. That influence should be small, however, since almost all groups contained nine or ten responses (a similar magnitude).

Scattergrams of the proportion of panelists reporting, f_g, were plotted against the average values of the air pollution variables OZONE, CO, NO_2, and TEMP. Superimposed on each were the linear probability estimate of the proportion and the LOGIT estimate of the proportion. The LOGIT probabilities were plotted by computing the predicted θ for several values of the explanatory variable using the transformation

$$\theta = 1/\left\{1 + \exp\left[-(\beta_0 + \beta_1 \bar{X})\right]\right\}$$

where β_0 and β_1 were taken from the results of the LOGIT regression.

Comparison of the two plotted curves for all four cases indicated that the linear specification provides a close approximation to the probabilities predicted by the LOGIT, but as the plots are extrapolated beyond the original range of the dates, the plots diverge. In the case with NO_2 as the explanatory variable, the linear function gives a probability greater than one when NO_2 reaches 0.27 ppm. At the same time, the LOGIT plot is asymptotic to the 0 and 1 limits. Therefore, the LOGIT would provide more realistic predictions at the extremes of the explanatory variable.

Multiple LOGIT Regression Using EYES and HEADACHE

Multi-LOGIT regression specifies the probability (or proportion) of an event occurring (panelists experiencing eye discomfort or headache) as a function of several explanatory variables simultaneously. Multi-LOGIT regression is the multiple variable extension of simple LOGIT regression which uses a single explanatory variable. The results reported in Table 24 and Table 25 use the LOGIT estimate of $\theta/(1 - \theta)$ where the proportion of panelists reporting eye discomfort or headache were substituted as estimates of θ, the probability of experiencing the discomfort symptom.

The LOGIT results using the proportion of panelists reporting eye discomfort are reported in Table 24. Five variations in the LOGIT model were estimated. The first two were estimated for all sub-panels simultaneously. The last three were estimated while excluding Sub-Panel 4. The last regression included dummy variables for the sub-panels: Sub-Panel (Group) 1 is the base; G2 = 1 if the observation was for Sub-Panel (Group) 2; G3 = 1 if the observation was for Sub-Panel (Group) 3. The first, third, and fifth regressions used the weighted average of the hourly averages of OZONE, CO, NO$_2$, and TEMP as explanatory variables. (See Appendix I for an explanation of how the weighted averages were derived.) The second and fourth regressions used the daily maximum of the hourly averages of the same air pollution variables as explanatory.

In Table 24, Equation 1 (shown as Column 1) has an R^2 = 0.41 and only average temperature (AVETEMP) has a coefficient significantly different from zero. Equation 2 has an R^2 = 0.40 and only maximum ozone (MAXOZ) has a coefficient significantly different from zero. The Durbin-Watson (D.W.) test for serial correlation is indeterminate for Equation 1, but indicates positive serial correlation for Equation 2.

When the Sub-Panel 4 is excluded the results change. Equation 3 has an R^2 = 0.73, and the Durbin-Watson statistic is still indeterminate in its indication of serial correlation. Average nitrogen dioxide (AVENO2) now has a significantly positive coefficient, but none of the other coefficients are significantly different from zero. Equation 4, using the maximums of the air pollution variables, has an R^2 = 0.28, the lowest of all the LOGIT regressions using eye discomfort. None of the coefficients in Equation 4 are statistically significant at α = 0.10.

Equation 5 was estimated using the averages of the air pollution variables, excluded Sub-Panel 4, and utilized dummy variables for the remaining groups. The coefficients of determination for Equation 5 was R^2 = 0.76. Furthermore, the Durbin-Watson coefficient leads to acceptance of a null hypothesis of

TABLE 24. MULTIPLE LOGIT PROBABILITY REGRESSIONS WITH PROPORTION OF EYE DISCOMFORT AS THE DEPENDENT VARIABLE (STANDARD ERRORS IN PARENTHESES)

Variable	(1) All Sub-Panels	(2) All Sub-Panels	(3) Three Sub-Panels	(4) Three Sub-Panels	(5) Three Sub-Panels
AVEOZ	11.74 (8.67)		3.03 (2.89)		6.35* (3.43)
AVECO	7.76 (20.96)		-6.79 (7.05)		-7.66 (7.40)
AVENO2	5.90 (12.86)		16.71* (4.50)		14.31* (4.66)
AVETEMP	0.12* (0.05)		-0.01 (0.02)		-0.01 (0.02)
MAXOZ		11.53* (6.66)		2.73 (2.72)	
MAXCO		-38.16 (34.07)		15.23 (14.97)	
MAXNO2		2.24 (3.02)		1.71 (1.18)	
MAXTEMP		0.11* (0.04)		-0.01 (0.02)	
G2	---	---	---	---	0.24 (0.33)
G3	---	---	---	---	0.64 (0.37)
CONSTANT	-12.32	-9.95	-1.04	-0.84	-1.25
R^2	0.41	0.41	0.73	0.28	0.76
F	6.00	5.41	7.04	2.53	5.38
N	40	40	30	30	30
D.W.	1.19***	1.11****	1.53***	1.61***	1.86**

*Significant for two-tailed test with $\alpha = 0.10$

**Accept null hypothesis of no serial correlations at $\alpha = 0.05$

***Durbin-Watson test for serial correlation indeterminate at $\alpha = 0.05$

****Positive serial correlation at $\alpha = 0.05$

TABLE 25. MULTIPLE LOGIT PROBABILITY REGRESSIONS WITH PROPORTION
OF HEADACHE AS THE DEPENDENT VARIABLE
(STANDARD ERRORS IN PARENTHESES)

Variable	(1) All Sub-Panels	(2) All Sub-Panels	(3) Three Sub-Panels	(4) Three Sub-Panels	(5) Three Sub-Panels
AVEOZ	0.14 (8.02)		-0.39 (3.26)		1.83 (2.96)
AVECO	23.24 (19.38)		1.30 (7.90)		-7.78 (6.16)
AVENO2	-0.05 (11.89)		5.00 (4.97)		6.50* (3.91)
AVETEMP	0.16* (0.04)		0.04* (0.02)		0.02 (0.02)
MAXOZ		8.03 (6.04)		3.15 (2.32)	
MAXCO		-5.39 (30.89)		3.15 (13.00)	
MAXNO2		-0.25 (2.74)		-0.72 (1.00)	
MAXTEMP		0.11* (0.04)		0.03 (0.02)	
G2	---	---	---	---	-1.05* (0.28)
G3	---	---	---	---	0.23 (0.31)
CONSTANT	-14.83	-11.84	-4.70	-4.26	-2.62
R^2	0.41	0.43	0.25	0.32	0.63
F	6.11	6.62	1.90	2.65	5.85
N	40	40	28	28	28
D.W.	1.86*	1.85*	1.14**	1.27***	2.31***

*Significant for two-tailed test with $\alpha = 0.10$

**Accept null hypothesis of no serial correlations at $\alpha = 0.05$

***Durbin-Watson test for serial correlation indeterminate at $\alpha = 0.05$

no serial correlation at $\alpha = 0.05$. Serial correlation is not a problem when the group dummy variables are included. AVEOZ and AVENO2 are positive in sign and statistically significant. AVECO and AVETEMP do not have coefficients significantly different from zero.

The multi-LOGIT regressions using the proportions of panelists reporting headache in Table 25 follow the same pattern. Equations 1 and 2 using all groups have $R^2 = 0.41$ and $R^2 = 0.43$, respectively. Only the temperature variables have significant coefficients. The test for serial correlation leads to acceptance of the hypothesis of no serial correlation. Equation 3 has $R^2 = 0.25$ with AVETEMP having the only statistically significant coefficient. None of the coefficients in Equation 4 are significant. Both of the regressions which exclude Sub-Panel 4, are significant. Both of the regressions which exclude Sub-Panel 4, Equations 3 and 4, have Durbin-Watson statistics in the indeterminate range.

Again, Equation 5 yields the best results for the LOGIT transformation of the proportion of panelists reporting headache. The coefficient of determination is $R^2 = 0.63$. The equation excluded Sub-Panel 4 and utilized dummy variables for the remaining groups. The only pollution variable having a significant coefficient is AVENO2. The test for serial correlation is indeterminate.

Summary of the Analysis by Date

The multi-LOGIT approach to estimating the probability of a qualitative dependent variable is a useful extension of the simple LOGIT which is consistent with the probability interpretation. There was no indication that serial correlation was a serious problem when Sub-Panel 4 was excluded or the group dummy variables were used to control for between group differences. The results which explained the greatest variance are shown in Equation 5. Equation 5 using eye discomfort indicates a positive influence of OZONE and NO_2. For the headache symptom, Equation 5 indicates a positive influence of NO_2.

MULTIVARIATE ANALYSIS OF MAXFEV

Two multivariate regression models were used to explain variations in MAXFEV, while controlling for differences between individuals. Following this, multivariate regressions were attempted with the air pollution variables lagged. The extent to which variations in MAXFEV were explained by differences between individuals and differences in levels of air pollution are provided in this concluding discussion of the asthma panel.

The Hasselblad Model

A specific model developed by Dr. Victor H. Hasselblad for analysis on a St. Louis data set similar to that of the present study makes use of dummy variables which control for differences between individuals. The form of model is:

$$FEV_{ij} = \beta_0 + \sum_{m=1}^{n-1} \beta_m P_{mj} + \sum_{r=n}^{s} \beta_r X_{rj} + \varepsilon_{ij}$$

for $i = 1,\ldots,n$ and $j = 1,\ldots,k$. The variable P_{mj} is defined by:

$$P_{mj} = 1 \text{ if } i < m + 1$$

$$P_{mj} = -m \text{ if } i = m + 1$$

$$P_{mj} = 0 \text{ if } i > m + 1$$

where $m = 1,\ldots,n - 1$. Since this variable controls for differences between individuals, there is no need to include AGE, HEIGHT, or COLD. The variable X_{1j} is the inverse of the day of the study; i.e., $X_{1j} = 1/k$. The other X_{rj} are air pollution variables which may be included separately or simultaneously. The ε_{ij} represents the random error term.

Translation of this notation into specific variables for the asthma panel results in 40 P_{mj} variables. These are named P1 to P40 since the dates of the study were numbered 1 to 40, the variable X_{1j} was named DINV which stands for day inverse. DINV = $1/k$ where $k = 1,\ldots,40$. The other explanatory variables were OZONE, CO, NO_2, and NO. Five regressions were performed. The first four used the air pollution variables separately; the last one used the air pollution variables simultaneously. The results are reported in Tables 26A through 26E.

All of the regressions have high R^2 values. In every case, more than 80 percent of the variation in MAXFEV was explained by regression. The total F indicates rejection of a hypothesis that all coefficients are zero at the same time. The Durbin-Watson test of serial correlation indicates acceptance of a null hypothesis of no serial correlation in all five regressions.

The data variable, DINV, is not statistically different from zero at a level of significance of $\alpha = 0.05$. The air pollution variables are never statistically significant from zero in any of the regressions. Many of the dummy variables for the individuals, P_{mj}, are statistically significant. Therefore,

TABLE 26A. HASSELBLAD REGRESSION ON MAXFEV (IN LITERS x 100) WITH OZONE

$R^2 = 0.81$, N = 379, Total F = 34.43, D.W. = 1.83

Variable	β	Standard Error	$F = t^2$
P1	-15.78957	10.89973	2.099
P2	-49.64007	5.34495	86.254
P3	40.86285	3.85492	112.364
P4	-11.35473	2.74903	17.061
P5	-8.84465	2.32977	14.412
P6	2.98894	1.83538	2.652
P7	-4.44504	1.65966	7.173
P8	-13.28890	1.39633	90.574
P9	-15.15549	1.25960	144.769
P10	-0.69572	1.12138	0.385
P11	1.56220	1.09826	2.023
P12	-6.79830	0.94663	51.575
P13	-5.60478	0.90126	38.674
P14	1.89075	0.81799	5.343
P15	-1.17128	0.77348	2.293
P16	-2.57055	0.73848	12.116
P17	-0.75333	0.71803	1.101
P18	-1.55023	0.64221	5.827
P19	-1.95164	0.62277	9.821
P20	2.91307	0.58772	24.568
P21	-1.14707	0.56549	4.115
P22	-2.52392	0.52646	22.983
P23	-6.14406	0.56551	118.038
P24	1.10657	0.48796	5.143
P25	6.28333	0.47256	176.790
P26	1.67245	0.47418	12.440
P27	1.91744	0.44963	18.186
P28	0.37725	0.90221	0.175
P29	-0.95427	0.44662	4.565
P30	3.90674	0.38572	102.587
P31	0.09962	0.37734	0.070
P32	0.08798	0.36622	0.058
P33	0.35763	0.35001	1.044
P34	1.27750	0.53058	5.797
P35	2.10680	0.33686	39.115
P36	-3.03290	0.32231	88.545
P37	-1.00258	0.32961	9.252
P38	-3.44107	0.30391	128.206
P39	-1.76191	0.29838	34.869
P40	0.39697	0.29685	1.738
DINV	20.94211	13.15471	2.534
OZONE	-24.04256	38.51230	0.390
CONSTANT	280.05108		

TABLE 26B. HASSELBLAD REGRESSION ON MAXFEV
(IN LITERS x 100) WITH CO

$R^2 = 0.81$, N = 378, Total F = 34.27, D.W. = 1.83

Variable	β	Standard Error	$F = t^2$
P1	-16.03449	10.88504	2.170
P2	-50.06063	5.31065	88.858
P3	40.68993	3.84776	111.830
P4	-11.62245	2.71202	18.366
P5	-8.50794	2.24869	14.315
P6	3.03131	1.83306	2.735
P7	-4.23387	1.61488	6.874
P8	-13.36425	1.38981	92.465
P9	-15.20223	1.26372	144.716
P10	-0.66490	1.12360	0.350
P11	1.68398	1.07569	2.451
P12	-6.86772	0.93934	53.454
P13	-5.50511	0.88259	38.906
P14	1.84561	0.82005	5.065
P15	-1.26273	0.75725	2.781
P16	-2.70575	0.72109	14.080
P17	-0.86611	0.70523	1.508
P18	-1.61008	0.63643	6.400
P19	-2.06079	0.60823	11.480
P20	2.82119	0.57750	23.865
P21	-1.26300	0.55570	5.166
P22	-2.56860	0.52305	24.116
P23	-6.09700	0.56039	118.372
P24	-1.05978	0.48106	4.853
P25	6.42707	0.48707	174.121
P26	1.59025	0.47066	11.416
P27	1.93044	0.44871	18.509
P28	0.35290	0.90286	0.153
P29	-0.98857	0.44357	4.967
P30	3.91339	0.38497	103.337
P31	0.10365	0.37704	0.076
P32	0.05318	0.36210	0.022
P33	0.37547	0.35079	1.146
P34	1.28370	0.53027	5.860
P35	2.07060	0.33163	38.984
P36	-3.06900	0.32197	90.269
P37	-1.02337	0.32898	9.677
P38	-3.44565	0.30416	128.334
P39	-1.79014	0.29692	36.350
P40	0.35730	0.29455	1.471
DINV	21.17709	13.27700	2.544
CO	-49.47883	166.74573	0.088
CONSTANT	279.61475		

TABLE 26C. HASSELBLAD REGRESSION ON MAXFEV (IN LITERS x 100) WITH NO2

$R^2 = 0.90$, N = 355, Total F = 31.23, D.W. = 1.82

Variable	β	Standard Error	$F = t^2$
P1	-6.03457	12.48188	0.234
P2	-48.30260	5.73542	70.927
P3	41.57889	4.03225	106.329
P4	-11.11454	2.82193	15.513
P5	-8.10130	2.31121	12.287
P6	3.58742	2.06781	3.010
P7	-4.04938	1.65494	5.987
P8	-13.18349	1.66631	62.596
P9	-15.08360	1.29482	135.703
P10	-0.57895	1.20447	0.231
P11	1.76683	1.12277	2.476
P12	-6.66454	1.00869	43.651
P13	-5.45445	0.90251	36.525
P14	1.89159	0.83532	5.128
P15	-1.24942	0.77355	2.609
P16	-2.66190	0.73332	13.176
P17	-0.82924	0.71759	1.335
P18	-1.58942	0.64948	5.989
P19	-2.02859	0.61858	10.755
P20	2.85027	0.58730	23.554
P21	-1.22332	0.55963	4.778
P22	-2.55197	0.53359	22.873
P23	-6.08941	0.57143	113.560
P24	1.16107	0.54584	4.525
P25	6.45446	0.49633	169.114
P26	1.61365	0.47591	11.448
P27	1.92868	0.45772	17.755
P28	0.36735	0.91864	0.160
P29	-1.02457	0.51909	3.896
P30	3.78322	0.41442	83.338
P31	0.11789	0.38364	0.094
P32	0.00412	0.38846	0.000
P33	0.27157	0.45564	0.355
P34	1.28877	0.54205	5.653
P35	1.96061	0.43366	20.441
P36	-3.04024	0.32784	86.000
P37	-1.00794	0.33586	9.006
P38	-3.44117	0.30957	123.563
P39	-1.77467	0.30313	34.276
P40	0.37584	0.29956	1.574
DINV	20.67062	13.42492	2.371
NO2	1.13692	36.64907	0.001
CONSTANT	278.07138		

TABLE 26D. HASSELBLAD REGRESSION ON MAXFEV (IN LITERS x 100) WITH NO

$R^2 = 0.80$, N = 353, Total F = 30.07, D.W. = 1.82

Variable	β	Standard Error	$F = t^2$
P1	-6.01690	12.52263	0.231
P2	-47.87112	5.76182	69.028
P3	41.87309	4.05034	106.878
P4	-10.74706	2.84165	14.303
P5	-8.34287	2.32496	12.877
P6	3.47027	2.19622	2.497
P7	-4.18557	1.66543	6.316
P8	-13.18164	1.67306	62.075
P9	-15.09640	1.29801	135.267
P10	-0.63051	1.20919	0.272
P11	1.67274	1.10471	2.293
P12	-6.62364	1.01282	42.769
P13	-5.51711	0.90432	37.220
P14	1.86695	0.83833	4.959
P15	-1.11378	0.78220	2.028
P16	-2.64092	0.73465	12.923
P17	-0.81075	0.71941	1.270
P18	-1.50242	0.65451	5.269
P19	-1.99574	0.62024	10.354
P20	2.85973	0.58864	23.602
P21	-0.91934	0.62424	2.169
P22	-2.46238	0.53871	20.893
P23	-6.15167	0.57497	114.472
P24	1.16900	0.54641	4.577
P25	6.26174	0.52835	140.455
P26	1.81273	0.49488	13.417
P27	1.98004	0.45984	18.541
P28	0.33477	0.92185	0.132
P29	-0.93198	0.48356	3.715
P30	3.75552	0.43792	73.545
P31	0.08415	0.38589	0.048
P32	0.13316	0.39061	0.116
P33	0.25651	0.45730	0.315
P34	1.25820	0.54248	5.379
P35	2.05933	0.40153	26.304
P36	-2.95713	0.33373	78.513
P37	-1.01671	0.33630	9.140
P38	-3.44263	0.31051	122.922
P39	-1.72127	0.30558	31.727
P30	0.36323	0.30001	1.466
DINV	17.09786	13.64908	1.569
NOX	426.68439	299.63223	2.028
CONSTANT	272.74778		

TABLE 26E. HASSELBLAD REGRESSION ON MAXFEV (IN LITERS x 100) WITH ALL AIR POLLUTION VARIABLES MEASURED DURING DAILY SURVEILLANCE OF THE ASTHMA PANEL

$R^2 = 0.80$, N = 348, Total F = 27.30, D.W. = 1.85

Variable	β	Standard Error	$F = t^2$
P1	-6.03019	12.59058	0.229
P2	-47.75923	5.85841	66.459
P3	41.89505	4.08670	105.095
P4	-10.67156	2.90616	13.484
P5	-8.52124	2.46456	11.954
P6	3.44262	2.21316	2.420
P7	-4.29493	1.74278	6.073
P8	-13.14384	1.70061	59.736
P9	-15.11353	1.31553	131.987
P10	-0.63022	1.22409	0.265
P11	1.52866	1.17651	1.688
P12	-6.57314	1.03991	39.953
P13	-5.59551	0.94089	35.367
P14	1.87400	0.85549	4.799
P15	-1.07335	0.80849	1.763
P16	-2.60215	0.81278	10.250
P17	-0.77691	0.77644	1.001
P18	-1.48500	0.67041	4.907
P19	-1.96360	0.67914	8.360
P20	2.88701	0.63551	20.637
P21	-0.90436	0.68120	1.763
P22	-2.45571	0.54946	19.975
P23	-6.16779	0.58746	110.232
P24	1.20496	0.56186	4.599
P25	6.89114	0.62121	123.057
P26	1.79579	0.52532	11.686
P27	1.95623	0.46663	17.575
P28	0.33042	0.93211	0.126
P29	-1.00745	0.52564	3.673
P30	3.75571	0.44239	72.073
P31	0.06279	0.38938	0.026
P32	0.08442	0.42043	0.040
P33	0.24113	0.46416	0.270
P34	1.26254	0.54750	5.318
P35	2.00120	0.44435	20.283
P36	-2.96381	0.33894	76.462
P37	-1.02273	0.34159	8.964
P38	-3.44270	0.31295	121.016
P39	-1.72659	0.31209	30.607
P40	0.36648	0.31735	1.334
DINV	16.93315	14.15700	1.431
OZONE	-11.68595	57.19537	0.042
CO	6.00126	269.56597	0.000
NO2	-12.73782	45.02380	0.080
NOX	407.04484	323.01965	1.588
CONSTANT	274.66639		

the conclusion is that most of the variation in MAXFEV is explained by differences between the individuals in the asthma panel rather than the levels of air pollution measured during daily surveillance.

Standard Linear Model

An alternative linear model utilizes a dummy variable for the sub-panels tested on different dates. Sub-Panel 1, tested on dates 1 to 10, was used as the base group. Variable G2 = 1 if the observation was for Sub-Panel 2; G3 = 1 if the observation was for Sub-Panel 3; G4 = 1 if the observation was for Sub-Panel 4. AGE and HEIGHT were also included as explanatory variables. A dummy variable to control for the panelist reporting a cold was included as an explanatory variable. HUMID and TEMP were included. The only air pollution measure included was CO, since prior analysis indicated this variable as potentially significant. The results are reported in Table 27.

TABLE 27. MULTIVARIATE REGRESSION OF MAXFEV WITH SUB-PANEL (GROUP) VARIABLES

$R^2 = 0.25$, N = 367, Total F = 13.27

Variable	β	Standard Error	$F = t^2$
AGE	-3.62**	0.52	47.77
HEIGHT	4.69**	1.34	12.26
G2	0.69	10.33	0.01
G3	-8.52	10.84	0.62
G4	-48.56**	14.78	10.79
COLD	-54.50	17.12	10.13
CO	31.35	315.92	0.01
HUMID	-0.15	0.73	0.04
TEMP	-0.10	0.77	0.02
CONSTANT	128.653		

**Significant at $\alpha = 0.05$

The only variables having estimated coefficients which are statistically different from zero are those associated with measuring differences between individuals, AGE, HEIGHT, COLD, and G4. Sub-Panel 4 is again significant as an explanatory variable capturing between group differences that were not captured by AGE, HEIGHT, and COLD.

None of the air pollution variables had estimated coefficients that were statistically different from zero. The conclusion is again that most of the variation in MAXFEV was explained by differences between the individuals in the asthma panel.

Lagged Pollution Variables

In an attempt to see if there was any cumulative or residual effects of air pollution on the pulmonary function variable, the air pollution variables were lagged one day. The results of the multivariate regression are shown in Table 28. The variable names are different to indicate that they are lagged. AGE and HEIGHT are the only variables that are statistically significant. None of the lagged air pollution variables contributes to the reduction in the explained variation in MAXFEV.

TABLE 28. MULTIVARIATE REGRESSION OF MAXFEV
WITH LAGGED AIR POLLUTION VARIABLES

R^2 = 0.204, N = 290, F = 7.988

Variable	β	Standard Error	$F = t^2$
AGE	-3.46	0.57	36.73
HEIGHT	5.63	1.45	15.07
COLD	-11.70	22.59	0.27
OZONE-1	64.71	126.59	0.26
CO-1	-185.51	394.52	0.22
NO2-1	17.65	25.61	0.47
NO-1	1,014.77	1,354.55	0.56
HUMID-1	-0.11	1.29	0.07
TEMP-1	-0.63	1.26	0.25

Summary of the Multivariate Analysis

Both the Hasselblad model and the alternate linear model include variables to control for differences in panelist characteristics. The Hasselblad model utilizes a dummy variable technique which assigns a value to separate variables for each individual in the study. The alternative model uses AGE and HEIGHT, as well as dummy variables for having a cold and for the four sub-panels.

The primary conclusion is that the variables which capture individual differences explain a large portion of the variance in the dependent variable MAXFEV. There is very little variation left to be explained by the air pollution variables. Therefore, it is concluded that MAXFEV was not statistically sensitive to the levels of air pollution monitored during daily surveillance of the asthma panel.

OVERALL SUMMARY OF THE ASTHMA PANEL DATA ANALYSIS

The levels of air pollution in the study area as monitored at the Los Angeles County Air Pollution Control District station in Azusa were light to moderate during the 40 days of asthma panel symptom surveillance. The average values of the aerometric variables at the times asthma panelists reported their symptoms (i.e., the weighted averages of these variables) are presented in Table 9C. The weighted averages of responses to daily symptom interviewing and to pulmonary function testing are shown in Tables 9A and 9B. The symptom and aerometric data are compared graphically in Appendix I.

The analysis of the symptom data showed that eye irritation was significantly correlated with all of the aerometric variables (Tables 10, 12, and 13). The discomfort symptom headache was significantly correlated with ozone, carbon monoxide, relative humidity, and temperature. There were few significant correlations between the other discomfort symptoms and the aerometric variables. Ozone was significantly correlated with the most discomfort symptoms. Ozone was positively correlated with reports of eye irritation, headache, shortness of breath, and production of phlegm.

The results regarding the measurement of maximum $FEV_{1.0}$, whether adjusted for age and height, adjusted by the ratio of maximum $FEV_{1.0}$/maximum FVC, or unadjusted maximum $FEV_{1.0}$ showed no linear association between pulmonary function and the aerometric variables. Most of the variation in maximum $FEV_{1.0}$ was explained by differences in the age and height of the panelists. The lack of association between pulmonary function and the aerometric variables may have been due to the generally low concentrations of air pollutants in the study area during the 40 days

of symptom surveillance. An additional explanation is that the asthma panelists tended to live fairly quiet lives by avoiding strenuous activities and staying indoors during the hours of the day when air pollution levels could be expected to be high.

SECTION 8

DATA ANALYSIS--OUTDOOR WORKER PANEL

STATISTICAL DESCRIPTION OF THE OUTDOOR WORKER PANEL

This panel was intended to be composed entirely of healthy outdoor workers. However, the comprehensive clinical examinations and interviews revealed that 7 of the 95 workers had symptoms of bronchitis and two others had active cases of asthma. Since the employers apparently considered all of the workers to be healthy enough to perform their assigned jobs, data were collected from all 95 workers. However, the analysis covers only the 85 workers for whom there was sufficient data and no indication of preexisting lung disease.

The outdoor worker panel was composed of both smokers and nonsmokers in the 21 to 50 age bracket. Slightly less than half were smokers. Like the asthma panel, the outdoor worker panel was divided into four sub-panels which were tested on four successive two-week periods. The composition of the sub-panels is shown in Table 29.

Description of the Variables

The discomfort symptom variables were recorded on the form shown in Appendix F. The variables were dichotomous and were coded so that "Yes" responses were equal to unity and "No" responses were equal to zero. A statistical profile of the discomfort variables is given in Table 30A. The variables were the same as those measured during daily surveillance of the asthma panel. Variable COLD was used to measure whether or not the panelist had a bad cold and MEDICINE was used to measure whether or not the panelist had taken any medicine on the day of testing.

A profile of the smoking variables is shown in Table 30B. Variable SMOKE was given a value of unity for each day the panelist had smoked during the two-week testing period and a value of zero for each day the panelist had not smoked during the same period. CIGARETTES indicate the number of cigarettes smoked each day.

Two pulmonary function variables were used in the analysis of the outdoor worker panel. Variable MAXFEV measured the

TABLE 29. COMPOSITION OF THE OUTDOOR WORKER SUB-PANELS

Characteristics	Sub-Panel 1	Sub-Panel 2	Sub-Panel 3	Sub-Panel 4	Total
Subjects enrolled in panel (all male)	18	24	26	18	86
Current cigarette smokers	8	14	9	8	39
Subjects 21 to 30 years old	5	4	2	7	18
Subjects 31 to 40 years old	3	8	15	4	30
Subjects 41 to 50 years old	10	12	9	7	38
Subjects with 12 or more years of school completed	17	19	24	15	75
Race other than white	0	8	3	5	16

TABLE 30A. STATISTICAL PROFILE OF DISCOMFORT SYMPTOM VARIABLES MEASURED DURING OUTDOOR WORKER PANEL SURVEILLANCE

VARIABLE: EYES = Eye discomfort now

MEAN	= 0.174	RANGE	= 1.000
VARIANCE	= 0.144	MINIMUM	= 0.000
KURTOSIS	= 0.977	MAXIMUM	= 1.000
STD DEV	= 0.379	VALID OBS	= 899
SKEWNESS	= 1.726	MISSING OBS	= 0

VARIABLE: HEADACHE EARLIER = Headache earlier today

MEAN	= 0.088	RANGE	= 1.000
VARIANCE	= 0.080	MINIMUM	= 0.000
KURTOSIS	= 6.487	MAXIMUM	= 1.000
STD DEV	= 0.283	VALID OBS	= 899
SKEWNESS	= 2.915	MISSING OBS	= 0

VARIABLE: THROAT = Throat discomfort now

MEAN	= 0.132	RANGE	= 1.000
VARIANCE	= 0.115	MINIMUM	= 0.000
KURTOSIS	= 2.714	MAXIMUM	= 1.000
STD DEV	= 0.339	VALID OBS	= 899
SKEWNESS	= 2.172	MISSING OBS	= 0

VARIABLE: BREATH = Shortness of breath today

MEAN	= 0.088	RANGE	= 1.000
VARIANCE	= 0.080	MINIMUM	= 0.000
KURTOSIS	= 6.487	MAXIMUM	= 1.000
STD DEV	= 0.283	VALID OBS	= 899
SKEWNESS	= 2.915	MISSING OBS	= 0

VARIABLE: CHEST = Chest discomfort now

MEAN	= 0.149	RANGE	= 1.000
VARIANCE	= 0.127	MINIMUM	= 0.000
KURTOSIS	= 1.890	MAXIMUM	= 1.000
STD DEV	= 0.356	VALID OBS	= 899
SKEWNESS	= 1.973	MISSING OBS	= 0

VARIABLE: COUGH = Cough today

MEAN	= 0.356	RANGE	= 1.000
VARIANCE	= 0.230	MINIMUM	= 0.000
KURTOSIS	= -1.636	MAXIMUM	= 1.000
STD DEV	= 0.479	VALID OBS	= 899
SKEWNESS	= 0.602	MISSING OBS	= 0

VARIABLE: HEADACHE = Headache now

MEAN	= 0.060	RANGE	= 1.000
VARIANCE	= 0.057	MINIMUM	= 0.000
KURTOSIS	= 11.728	MAXIMUM	= 1.000
STD DEV	= 0.238	VALID OBS	= 899
SKEWNESS	= 3.707	MISSING OBS	= 0

VARIABLE: PHELGM = Phlegm today

MEAN	= 0.719	RANGE	= 1.000
VARIANCE	= 0.203	MINIMUM	= 0.000
KURTOSIS	= -1.988	MAXIMUM	= 1.000
STD DEV	= 0.450	VALID OBS	= 317
SKEWNESS	= -0.980	MISSING OBS	= 3

VARIABLE: NAUSEA = Nausea now

MEAN	= 0.014	RANGE	= 1.000
VARIANCE	= 0.014	MINIMUM	= 0.000
KURTOSIS	= 64.243	MAXIMUM	= 1.000
STD DEV	= 0.119	VALID OBS	= 899
SKEWNESS	= 8.143	MISSING OBS	= 0

VARIABLE: COLD = Bad cold today

MEAN	= 0.106	RANGE	= 1.000
VARIANCE	= 0.095	MINIMUM	= 0.000
KURTOSIS	= 4.590	MAXIMUM	= 1.000
STD DEV	= 0.308	VALID OBS	= 899
SKEWNESS	= 2.568	MISSING OBS	= 0

VARIABLE: OTHER = Other discomfort now

MEAN	= 0.257	RANGE	= 1.000
VARIANCE	= 0.191	MINIMUM	= 0.000
KURTOSIS	= -0.760	MAXIMUM	= 1.000
STD DEV	= 0.437	VALID OBS	= 899
SKEWNESS	= 1.114	MISSING OBS	= 0

VARIABLE: MEDICINE = Medicine today

MEAN	= 0.166	RANGE	= 1.000
VARIANCE	= 0.138	MINIMUM	= 0.000
KURTOSIS	= 1.237	MAXIMUM	= 1.000
STD DEV	= 0.372	VALID OBS	= 899
SKEWNESS	= 1.800	MISSING OBS	= 0

TABLE 30B. STATISTICAL PROFILE OF SMOKING VARIABLES MEASURED DURING OUTDOOR WORKER PANEL SURVEILLANCE

VARIABLE: SMOKE = Smoke today

MEAN	=	0.399	RANGE	=	1.000
VARIANCE	=	0.240	MINIMUM	=	0.000
KURTOSIS	=	-1.830	MAXIMUM	=	1.000
STD DEV	=	0.490	VALID OBS	=	899
SKEWNESS	=	0.412	MISSING OBS	=	0

VARIABLE: CIGARETTES = Number of cigarettes smoked today

MEAN	=	6.063	RANGE	=	50.000
VARIANCE	=	84.948	MINIMUM	=	0.000
KURTOSIS	=	2.876	MAXIMUM	=	50.000
STD DEV	=	9.217	VALID OBS	=	899
SKEWNESS	=	1.668	MISSING OBS	=	0

maximum $FEV_{1.0}$ score of three maneuvers attained each day by each panelist. MAXFVC was the largest of two FVCs, one being the maximum FVC score recorded at the clinical examination pre-ceeding the two-week testing period, the other being the maximum FVC score recorded at the clinical examination following the testing period. The AGE and HEIGHT of each panelist were re-corded as age in years and standing height in inches. These data were used to adjust the MAXFEV and MAXFVC scores prior to analysis. A profile of the MAXFEV, MAXFVC, AGE, and HEIGHT variables is given in Table 30C. MAXFEV and MAXFVC are shown in hundred liters (liters x 100).

The air pollution and weather variables used in this analysis are the same as those used in the asthma panel analysis. A profile of these variables is given in Table 30D. The air pollution variables were obtained as hourly averages measured in ppm (CO in ppm/100). Relative humidity was estimated by hour and expressed in percent. A discussion on how the estimates were made is given in the paragraphs in Section 7 which describe the variables used in the asthma panel analysis. Temperature was obtained as hourly averages measured in degrees Fahrenheit.

There were no missing observations for any of the discom-fort symptom variables, and none were missing for COLD, MEDI-CINE, SMOKE, CIGARETTES, AGE, or HEIGHT. There were a large number of unrecorded FEV scores, but a sufficient number of ob-servations were recorded to maintain statistical credibility. Very few FVC scores were missing. There were a few missing ob-servations for the air pollution variables, but they were not large in number. There were no missing observations for HUMID and TEMP.

Although most of the members of the outdoor worker panel were tested over fewer hours than members of the asthma panel, weighted averages of exposure to air pollutant, humidity, and temperature levels were used in the analysis of the outdoor worker panel also. Once again, the hour at which each panelist reported for testing was noted and the aerometric values for that hour were included in the weighted average for that day.

The proportions of outdoor worker panelists who reported discomfort symptoms are shown in Appendix J for each of the 54 days when symptom data were collected. The weighted averages of the air pollutants, relative humidity, and temperature are also given in Appendix J for each of the same days. The charts are provided to facilitate comparisons between proportions of panel-ists who reported symptoms and the weighted averages of air pollution.

TABLE 30C. STATISTICAL PROFILE OF PULMONARY FUNCTION MEASURED DURING OUTDOOR WORKER PANEL SURVEILLANCE

VARIABLE: MAXFEV = Maximum $FEV_{1.0}$ (in liters x 100)

MEAN	=	376.627	RANGE	=	370.000
VARIANCE	=	5,671.790	MINIMUM	=	190.000
KURTOSIS	=	-0.118	MAXIMUM	=	560.000
STD DEV	=	75.311	VALID OBS	=	762
SKEWNESS	=	0.094	MISSING OBS	=	137

VARIABLE: MAXFVC = Maximum FVC (in liters x 100)†

MEAN	=	570.351	RANGE	=	490.000
VARIANCE	=	7,334.533	MINIMUM	=	305.000
KURTOSIS	=	1.586	MAXIMUM	=	795.000
STD DEV	=	85.642	VALID OBS	=	894
SKEWNESS	=	0.828	MISSING OBS	=	5

VARIABLE: AGE = Age of panelist (in years)

MEAN	=	38.616	RANGE	=	25
VARIANCE	=	60.616	MINIMUM	=	25
KURTOSIS	=	-1.085	MAXIMUM	=	50
STD DEV	=	7.786	VALID OBS	=	86
SKEWNESS	=	-0.331	MISSING OBS	=	0

VARIABLE: HEIGHT = Height in panelist (in inches)

MEAN	=	68.440	RANGE	=	13
VARIANCE	=	5.165	MINIMUM	=	63
KURTOSIS	=	0.626	MAXIMUM	=	76
STD DEV	=	2.273	VALID OBS	=	84
SKEWNESS	=	0.262	MISSING OBS	=	2

†Largest of maximum FVC scores attained from clinical examination, and during daily surveillance.

TABLE 30D.   STATISTICAL PROFILE OF AIR POLLUTION
VARIABLES MEASURED DURING OUTDOOR WORKER
PANEL SURVEILLANCE

VARIABLE: OZONE = Estimate for oxidant (in ppm)

MEAN	=	0.080	RANGE	=	0.300
VARIANCE	=	0.004	MINIMUM	=	0.010
KURTOSIS	=	0.627	MAXIMUM	=	0.310
STD DEV	=	0.065	VALID OBS	=	882
SKEWNESS	=	1.173	MISSING OBS	=	17

VARIABLE: CO = Carbon monoxide (in ppm/100)

MEAN	=	0.036	RANGE	=	0.060
VARIANCE	=	0.000	MINIMUM	= .	0.010
KURTOSIS	=	0.309	MAXIMUM	=	0.070
STD DEV	=	0.011	VALID OBS	=	893
SKEWNESS	=	0.544	MISSING OBS	=	6

VARIABLE: NO2 = Nitrogen dioxide (in ppm)

MEAN	=	0.077	RANGE	=	0.280
VARIANCE	=	0.002	MINIMUM	=	0.010
KURTOSIS	=	7.122	MAXIMUM	=	0.290
STD DEV	=	0.041	VALID OBS	=	848
SKEWNESS	=	1.971	MISSING OBS	=	51

VARIABLE: NO = Nitric oxide (in ppm)

MEAN	=	0.020	RANGE	=	0.150
VARIANCE	:=	0.000	MINIMUM	=	0.010
KURTOSIS	=	16.607	MAXIMUM	=	0.160
STD DEV	:=	0.022	VALID OBS	=	876
SKEWNESS	=	3.757	MISSING OBS	=	23

VARIABLE: HUMID = Relative humidity (in percent)

MEAN	=	59.793	RANGE	=	25.000
VARIANCE	=	89.677	MINIMUM	=	50.000
KURTOSIS	=	-1.133	MAXIMUM	=	75.000
STD DEV	=	9.470	VALID OBS	=	899
SKEWNESS	=	0.418	MISSING OBS	=	0

VARIABLE: TEMP = Temperature (in degrees
Fahrenheit)

MEAN	=	73.112	RANGE	=	43.000
VARIANCE	=	114.389	MINIMUM	=	53.000
KURTOSIS	=	-0.635	MAXIMUM	=	96.000
STD DEV	=	10.695	VALID OBS	=	899
SKEWNESS	=	0.332	MISSING OBS	=	0

CORRELATION ANALYSIS

The results of performing Pearson and non-parametric corre-
lation analyses on the outdoor worker panel data are reported on
the following pages.

Pearson Correlation

The Pearson correlation coefficients for the outdoor worker
panel are shown in Table 31. The discomfort symptoms which are
significantly related to the air pollution variables at the α =
0.01 and α = 0.05 levels of significance are EYES, THROAT,
CHEST, BREATH, COUGH, AND PHLEGM. EYES, the most significant
discomfort symptom with respect to air pollution, is significant
at α = 0.01 when correlated with OZONE, NO, HUMID, and TEMP.
OZONE and TEMP are positively related to EYES, while NO and
HUMID are negatively related with less magnitude. CHEST is pos-
itively correlated with OZONE and TEMP at α = 0.01 and α = 0.05,
respectively. MAXFEV is not significantly correlated with any
air pollution variable, but the sign of the relationship is fre-
quently negative.

COUGH and PHLEGM are positively correlated with OZONE, at
the α = 0.01 and α = 0.10 levels of significance, respectively.
PHLEGM is inversely related to CO and NO_2 at α = 0.01. The fre-
quency of significant relationships between BREATH, COUGH, and
PHLEGM and the air pollution variables, and the fact that the
outdoor worker panel consists of both smokers and nonsmokers,
suggests that an analysis of differences between these two
groups would be appropriate to determine if lung discomforts
are due solely to the air pollutants or to a combination of air
pollutants and individual characteristics such as smoking.

Non-Parametric Correlations

The Spearman correlation coefficients reported in Table 32
and the Kendall correlation coefficients reported in Table 33
for the outdoor worker panel confirm the relationship indicated
by the Pearson correlation coefficients for most pairs. Several
discomfort symptoms are correlated with the air pollution vari-
ables at the α = 0.01 and α = 0.05 levels of significance:
EYES, THROAT, CHEST, BREATH, COUGH, and PHLEGM. EYES is the
symptom which is most significantly related with OZONE, NO, HUMID,
and TEMP, having non-parametric coefficients of the same magni-
tude as the Pearson coefficients.

CHEST is positively related to OZONE and TEMP, as shown in
the Pearson results, but the non-parametric correlations are
more significant. Moreover, the Kendall correlation between
CHEST and NO is now significantly negative. BREATH is signifi-
cantly related to OZONE, NO, and TEMP at the α = 0.01 level.

TABLE 31. PEARSON CORRELATION COEFFICIENTS FOR THE OUTDOOR WORKER PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.38***	0.07**	0.06*	-0.16***	-0.12***	0.26***
THROAT	0.04	0.01	0.04	-0.02	-0.08**	0.03
CHEST	0.16***	0.03	-0.00	-0.04	-0.03	0.07**
HEADACHE	0.01	0.05	0.03	-0.02	-0.00	-0.00
NAUSEA	-0.02	-0.02	-0.00	0.02	-0.02	-0.02
OTHER	0.04	-0.02	-0.01	-0.06*	-0.05	0.03
HEADACHE EARLIER	0.03	-0.01	-0.02	-0.05	-0.02	0.03
BREATH	0.19***	0.04	-0.02	-0.06*	0.01	0.09***
COUGH	0.14***	-0.04	-0.08**	-0.04	0.01	0.06*
PHLEGM	0.09*	-0.16***	-0.13***	-0.08	-0.01	0.07
MAXFEV	-0.02	-0.03	-0.00	-0.00	0.01	0.02
MAXFVC	-0.08**	-0.03	0.02	0.02	0.01	-0.05

*Significant at α = 0.10
**Significant at α = 0.05
***Significant at α = 0.01

TABLE 32. SPEARMAN CORRELATION COEFFICIENTS FOR THE OUTDOOR WORKER PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.36***	0.07**	0.06**	-0.20***	-0.12***	0.28***
THROAT	0.03	0.00	0.04	-0.03	-0.08***	0.04
CHEST	0.15***	0.17	0.02	-0.10***	-0.03	0.08***
HEADACHE	-0.01	0.05*	0.02	0.02	-0.00	-0.01
NAUSEA	-0.03	-0.02	0.00	0.01	-0.02	-0.03
OTHER	0.02	-0.04	-0.01	-0.04	-0.05*	0.03
HEADACHE EARLIER	0.00	-0.00	-0.01	-0.02	-0.02	0.02
BREATH	0.17***	0.04	0.02	-0.11***	0.01	0.10***
COUGH	0.14***	-0.06**	-0.07	-0.10***	0.02	0.07**
PHLEGM	0.11**	-0.17***	-0.07*	-0.19***	0.00	0.07*

*Significant at α = 0.10

**Significant at α = 0.05

***Significant at α = 0.01

TABLE 33. KENDALL CORRELATION COEFFICIENTS FOR THE OUTDOOR WORKER PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.30***	0.06**	0.05**	-0.19***	-0.11***	0.23***
THROAT	0.02	0.00	0.03	-0.03	-0.07***	0.04
CHEST	0.12***	0.02	0.02	-0.09***	-0.03	0.07***
HEADACHE	-0.01	0.04*	0.02	0.02	-0.00	-0.00
NAUSEA	-0.03	-0.01	0.00	0.01	-0.02	-0.02
OTHER	0.02	-0.03	-0.01	-0.04	-0.05*	0.03
HEADACHE EARLIER	0.00	-0.00	-0.01	-0.01	-0.02	0.02
BREATH	0.14***	0.04	0.02	-0.10***	0.01	-0.08***
COUGH	0.12***	-0.05**	-0.06**	-0.10***	0.02	0.06**
PHLEGM	0.09**	-0.16***	-0.06*	-0.18***	0.00	0.06*

*Significant at α = 0.10

**Significant at α = 0.05

***Significant at α = 0.01

BREATH is positively correlated with OZONE and TEMP, but inversely correlated with NO. COUGH is directly related to OZONE and TEMP at the $\alpha = 0.01$ and $\alpha = 0.05$ levels of significance, respectively. COUGH is negatively related to CO and NO at $\alpha = 0.05$ and $\alpha = 0.01$, respectively. PHLEGM is positively correlated with OZONE and TEMP at significance levels of $\alpha = 0.05$ and $\alpha = 0.10$, but PHLEGM is negatively correlated with CO and NO at $\alpha = 0.01$.

NAUSEA and HEADACHE EARLIER do not appear to be associated with any of the air pollution variables. This is true whether one examines the Pearson or non-parametric correlation coefficients.

The similarity of correlation between the lung variables, BREATH, COUGH and PHLEGM, and the air pollution variables in both the Pearson and non-parametric correlations suggests reliability of the results. The number of significant correlations for this panel is strikingly larger than the number of significant correlations for the asthma, bronchitis, and athlete panels. In fact, one must conclude from the correlation analysis that the panel of healthy outdoor workers was more sensitive to air pollution than were members of the other three panels. The correlations between the lung variables and the air pollution variables are again examined in the following pages, but this time separately for the smokers and nonsmokers.

Pearson Correlation for Smokers

Pearson correlation coefficients for the smokers in the outdoor worker panel are summarized in Table 34. EYES, THROAT, CHEST, HEADACHE, NAUSEA, OTHER, BREATH, COUGH, PHELGM, and MAXFEV are correlated with the air pollution data at the $\alpha = 0.01$ or $\alpha = 0.05$ level of significance. Thus, there are more significant correlations for smokers than for the panel as a whole.

EYES is significantly correlated at $\alpha = 0.01$ with OZONE, NO, HUMID, and TEMP. There is a positive relation between EYES and OZONE and TEMP, and there is a smaller, negative relation between EYES and NO and HUMID. THROAT is positively related to OZONE and CO at $\alpha = 0.05$. CHEST is significantly related to OZONE at $\alpha = 0.01$. HEADACHE, which was not significant when analyzing the entire panel, is positively correlated with OZONE and CO at $\alpha = 0.05$. NAUSEA is another discomfort symptom which was not significant when all workers were analyzed, but for smokers alone it is significantly correlated with HUMID at $\alpha = 0.05$. The sign of this relationship is negative as it was for the entire panel.

BREATH, COUGH and PHLEGM are again correlated with air pollution variables. BREATH is positively related to OZONE, CO, and TEMP at $\alpha = 0.01$, $\alpha = 0.05$, and $\alpha = 0.01$, respectively.

TABLE 34. PEARSON CORRELATION COEFFICIENTS FOR SMOKERS IN
THE OUTDOOR WORKER PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.40***	0.08	0.04	-0.18***	-0.17***	0.36***
THROAT	0.11**	0.11**	0.04	-0.00	-0.04	0.05
CHEST	0.18***	0.04	0.03	-0.06	-0.00	0.09*
HEADACHE	0.13**	0.13**	-0.02	-0.02	0.02	0.05
NAUSEA	-0.04	-0.00	0.02	0.05	-0.12**	0.01
OTHER	0.11**	0.04	0.02	-0.07	-0.04	-0.00
HEADACHE EARLIER	0.11*	0.02	-0.09*	-0.08	0.01	0.07
BREATH	0.31***	0.11**	0.03	-0.08	-0.02	0.19***
COUGH	0.18***	-0.03	-0.13**	-0.06	0.07	0.09*
PHLEGM	0.04	-0.14**	-0.04	-0.07	-0.01	0.02
MAXFEV	0.14**	-0.04	-0.12**	-0.11**	0.02	0.11**
MAXFVC	-0.08	-0.02	0.00	-0.03	0.01	-0.09*

*Significant at α = 0.10

**Significant at α = 0.05

***Significant at α = 0.01

COUGH is positively related to OZONE at α = 0.10, and negatively related to NO₂ at α = 0.05. PHLEGM is negatively correlated with CO at α = 0.05. Comparing the Pearson correlations for smokers to those for the entire panel, it is evident that there are more significant correlations for smokers, and the sign of those correlations is the same for most pairs.

Spearman and Kendall Correlations for Smokers

The Spearman and Kendall correlation coefficients are shown in Tables 35 and 36. Note that the Spearman and Kendall results strongly agree with the Pearson results for most pairs. BREATH is one discomfort symptom which has a higher number of significant correlations in the non-parametric results. More reliability should be placed on the non-parametric correlation analysis, since the data for the discomfort symptoms do not represent a continuous, cardinal form of measurement.

Pearson Correlation Coefficients for Nonsmokers

Pearson correlation coefficients for nonsmokers in the outdoor worker panel are shown in Table 37. Variables EYES, THROAT, CHEST, COUGH, PHLEGM and MAXFEV are significantly correlated with the air pollution variables at the α = 0.01 or α = 0.05 levels of significance. The total number of significant correlations is smaller for the nonsmokers than those for the entire panel. This may be an indication that smoking is another variable to be considered when analyzing sensitive or insensitive subsets.

EYES is positively correlated with OZONE and TEMP at the α = 0.01 level of significance. EYES is negatively correlated with NO at α = 0.01 and with HUMID at α = 0.05. THROAT is negatively related to HUMID and COUGH is positively related to OZONE at the α = 0.01 level of significance. HEADACHE, NAUSEA, OTHER, and HEADACHE EARLIER, are not significantly related to the air pollution variables at α = 0.01 or α = 0.05.

The number of significant correlations for the lung variables BREATH, COUGH, and PHLEGM is much lower than those for smokers and the panel as a whole. BREATH is not significantly paired with any air pollution variable at the α = 0.01 or α = 0.05 level of significance. COUGH and PHLEGM are positively correlated with OZONE at α = 0.01. The absence of significant correlations between the lung variables and the rest of the air pollution variables supports the conclusion that smoking is a significant variable in the analysis of discomfort symptoms.

MAXFEV is negatively correlated with OZONE at the α = 0.01 level of significance. The direction of this relationship is consistent with the rest of the panels, as would be expected. However, this is the only group in any of the panels studied

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TABLE 35. SPEARMAN CORRELATION COEFFICIENTS FOR SMOKERS IN
THE OUTDOOR WORKER PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.39***	0.07*	0.04	-0.24***	-0.16***	0.38***
THROAT	0.10**	0.09*	0.06	-0.05	-0.03	0.06
CHEST	0.17***	0.03	0.04	-0.09**	0.00	0.09**
HEADACHE	0.11**	0.13*	0.01	-0.04**	0.00	0.04**
NAUSEA	-0.04	-0.01	0.01	0.02	-0.12**	-0.01
OTHER	0.10**	0.04	0.04	-0.05	-0.03	-0.01
HEADACHE EARLIER	0.09**	0.02	-0.08*	-0.09**	0.00	0.05
BREATH	0.27***	0.11**	0.07*	-0.13***	-0.02	0.18***
COUGH	0.20***	-0.05	-0.12**	-0.14***	0.07*	0.10**
PHLEGM	-0.03	-0.15**	-0.02	-0.12**	0.01	0.00

*Significant at α = 0.10

**Significant at α = 0.05

***Significant at α = 0.01

TABLE 36. KENDALL CORRELATION COEFFICIENTS FOR SMOKERS IN
THE OUTDOOR WORKER PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.33***	0.06*	0.04	-0.23***	-0.15***	0.31***
THROAT	0.08**	0.08*	0.05	-0.05	-0.03	0.05
CHEST	0.14***	0.03	0.03	-0.08**	0.00	0.07**
HEADACHE	0.09**	0.11***	0.01	-0.04	0.00	0.03
NAUSEA	-0.03	-0.01	0.01	0.02	-0.11**	-0.01
OTHER	0.08**	0.03	0.03	-0.05	-0.03	-0.01
HEADACHE EARLIER	0.08**	0.02	-0.07*	-0.09**	0.00	0.04
BREATH	0.22***	0.10**	0.06*	-0.13***	-0.02	0.15***
COUGH	0.17***	-0.05	-0.10**	-0.14***	0.07*	0.08**
PHLEGM	-0.02	-0.13**	-0.02	-0.11**	0.01	0.00

*Significant at α = 0.10

**Significant at α = 0.05

***Significant at α = 0.01

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TABLE 37.   PEARSON CORRELATION COEFFICIENTS FOR NONSMOKERS IN
THE OUTDOOR WORKER PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.37***	0.08*	0.08*	-0.14***	-0.10**	0.20***
THROAT	-0.02	-0.06	0.05	-0.30	-0.12***	0.02
CHEST	0.15***	0.05	0.01	-0.00	-0.07	0.06
HEADACHE	-0.08*	0.00	0.07	-0.01	-0.01	-0.04
NAUSEA	-0.01	-0.02	-0.01	-0.01	0.08*	-0.05
OTHER	0.01	-0.06	-0.02	-0.04	-0.07	0.04
HEADACHE EARLIER	-0.01	-0.03	0.02	-0.04	-0.04	0.00
BREATH	0.08*	0.00	-0.05	-0.02	0.04	0.01
COUGH	0.12***	0.00	-0.01	0.02	-0.04	0.05
PHLEGM	0.19***	-0.09	-0.11	-0.02	-0.05	0.07
MAXFEV	-0.13***	-0.05	0.03	0.05	0.01	-0.03
MAXFVC	-0.08	-0.05	0.01	-0.00	0.03	-0.04

*Significant at α = 0.10

**Significant at α = 0.05

***Significant at α = 0.01

where the MAXFEV was significantly related to any of the air pollution variables. And the signs of the estimated coefficients are in the direction expected. Healthy nonsmoking outdoor workers may be more responsive to acute photochemical air pollution than any of the other groups studied.

Spearman and Kendall Correlations for Nonsmokers

The Spearman correlation coefficients, Table 38, and Kendall correlation coefficients, Table 39, for nonsmokers reinforce the Pearson results. There are fewer significant correlations for nonsmokers than for the entire panel, especially for the lung variables BREATH, COUGH, and PHLEGM.

Variable EYES has the largest number of significant correlations with the air pollution variables. The direction and magnitude of the non-parametric correlations are smiliar to the Pearson correlations. This is true for THROAT also. Variable CHEST has more significant pairs in the non-parametric results. CHEST is positively correlated with OZONE at $\alpha = 0.01$ and TEMP at $\alpha = 0.05$, and it is negatively correlated with HUMID and NO at $\alpha = 0.05$. The larger number of significant correlations for CHEST indicates that the non-parametric analysis may capture associations which the Pearson analysis missed. HEADACHE, NAUSEA, and OTHER also have significant correlations which were not indicated in the Pearson results. The signs are consistent for both Pearson and non-parametric results. HEADACHE EARLIER is not significantly related to any pollution variable included in the study.

The lung variables, BREATH, COUGH, and PHLEGM, have few significant non-parametric correlations with the air pollution data. BREATH is not significantly related to any air pollution variables at $\alpha = 0.01$ or $\alpha = 0.05$. COUGH and PHLEGM are positively related to OZONE at $\alpha = 0.01$. PHLEGM is also significantly correlated with NO at $\alpha = 0.05$.

Summary of the Correlation Analysis

Both the Pearson and the non-parametric correlation coefficients for smokers, nonsmokers, and for the panel as a whole indicate that EYES is the most frequently significant of the discomfort symptoms correlated with the air pollution variables. The lung variables BREATH, COUGH, and PHLEGM have fewer significant correlations with the air pollution variables for nonsmokers than for smokers or for the panel as a whole. This suggests that the nonsmokers in the outdoor worker panel were less sensitive to air pollution. However, when MAXFEV is considered, the reverse seems to have been true. MAXFEV is negatively correlated with OZONE at $\alpha = 0.01$ only for the nonsmokers. In order to identify further differences which may be attributable

TABLE 38. SPEARMAN CORRELATION COEFFICIENTS FOR NONSMOKERS IN
THE OUTDOOR WORKER PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.33***	0.08**	0.07**	-0.17***	-0.09**	0.21***
THROAT	-0.04	-0.05	0.03	-0.01	-0.12***	0.03
CHEST	0.14***	0.04	0.03	-0.09**	-0.08**	0.08**
HEADACHE	-0.10	-0.01	0.04	0.07*	-0.00	-0.04
NAUSEA	-0.02	-0.01	0.00	0.00	0.07**	-0.05
OTHER	-0.03	-0.08**	-0.04	-0.02	-0.06*	0.06*
HEADACHE EARLIER	-0.05	-0.02	0.03	0.03	-0.03	-0.00
BREATH	0.07*	-0.00	-0.02	-0.06*	0.04	0.02
COUGH	0.10***	-0.02	-0.01	-0.02	-0.04	0.06*
PHLEGM	0.18***	-0.11*	-0.04	-0.13**	-0.05	0.08

*Significant at α = 0.10
**Significant at α = 0.05
***Significant at α = 0.01

TABLE 39. KENDALL CORRELATION COEFFICIENTS FOR NONSMOKERS IN
THE OUTDOOR WORKER PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.28***	0.07**	0.06**	-0.16***	-0.09**	0.18***
THROAT	-0.03	-0.05	0.02	-0.01	-0.12***	0.03
CHEST	0.12***	0.03	0.02	-0.08**	-0.07	0.06**
HEADACHE	-0.08**	-0.01	0.03	0.06*	-0.00	-0.03
NAUSEA	-0.02	-0.01	0.00	0.00	0.07**	-0.04
OTHER	-0.03	-0.07**	-0.03	-0.02	-0.06*	0.05*
HEADACHE EARLIER	-0.05	-0.02	0.03	0.03	-0.03	-0.00
BREATH	0.06*	-0.00	-0.02	-0.06*	0.04	0.02
COUGH	0.09***	-0.02	-0.00	-0.02	-0.04	-0.05*
PHLEGM	0.15***	-0.10*	-0.03	-0.12**	-0.04	0.07

*Significant at α = 0.10
**Significant at α = 0.05
***Significant at α = 0.01

to smoking, smokers and nonsmokers are tested separately in the remaining analyses of data collected from this panel.

MEASURES OF ASSOCIATION BETWEEN VARIABLES

Three measures of association are applied to the discomfort symptoms, smoking, pulmonary function, and air pollution variables in the following pages.

Simple Linear Regressions with $FEV_{1.0}$ and $FEV_{1.0}/FVC$

Single variable regressions were performed with MAXFEV as the dependent variable. None of the regressions using MAXFEV and data collected from the whole panel resulted in statistically significant results. However, significant results were obtained when the outdoor worker panel was divided into smokers and nonsmokers. The estimated equations are reported in Tables 40 and 41.

Variables OZONE, NO_2, NO, and TEMP are significantly related to MAXFEV for smokers at the $\alpha = 0.05$ level of significance. However, the sign of the coefficient for OZONE is positive. Variables CO and HUMIDITY are not significant for smokers. For nonsmokers, only OZONE is statistically significant at $\alpha = 0.01$, and the sign of the coefficient is now negative. None of the other air pollution variables are statistically significant for nonsmokers.

Regression equations were also estimated using maximum $FEV_{1.0}$ divided by maximum FVC as the dependent variable. The FVC score used for a panelist was the largest of two FVC scores obtained by the panelist, one recorded at the clinical examination given before the two weeks of daily surveillance and the other recorded at the clinical examination following daily surveillance. This MAXFVC variable was treated as a constant for a given individual. It does not vary with the air pollution values since it was not measured at the same time as MAXFEV and the air pollution variables. The transformation maximum $FEV_{1.0}/$ maximum FVC measures the proportion of MAXFEV with respect to MAXFVC. This transformation is intended to control for individual differences; therefore, when the transformation is used, it is not necessary (or appropriate) to control for age, height, or other characteristics of an individual that could influence MAXFEV. The regression results are reported in Tables 42 and 43.

Table 42 presents the results for smokers. NO_2 is the only air pollution variable that is not statistically significant. The results for nonsmokers, reported in Table 43, are comparable except that OZONE and NO_2 are not statistically significant. In

TABLE 40. SIMPLE REGRESSIONS WITH MAXFEV (IN LITERS x 100) AS DEPENDENT VARIABLE FOR SMOKERS

MAXFEV = 341.192 + 151.352(OZONE)**	R^2 = 0.020
MAXFEV = 362.554 - 262.267(CO)	R^2 = 0.002
MAXFEV = 371.185 - 237.880(NO2)**	R^2 = 0.015
MAXFEV = 362.791 - 586.121(NO)**	R^2 = 0.013
MAXFEV = 342.620 + 0.190(HUMID)	R^2 = 0.001
MAXFEV = 293.137 + 0.821(TEMP)**	R^2 = 0.013

**Significant at α = 0.05

TABLE 41. SIMPLE REGRESSIONS WITH MAXFEV (IN LITERS x 100) AS DEPENDENT VARIABLE FOR NONSMOKERS

MAXFEV = 404.462 - 149.976(OZONE)***	R^2 = 0.017
MAXFEV = 404.059 - 332.504(CO)	R^2 = 0.003
MAXFEV = 388.221 + 49.460(NO2)	R^2 = 0.001
MAXFEV = 387.640 + 291.371(NO)	R^2 = 0.003
MAXFEV = 387.930 + 0.073(HUMID)	R^2 = 0.000
MAXFEV = 409.055 - 0.227(TEMP)	R^2 = 0.001

***Significant at α = 0.01

TABLE 42. SIMPLE REGRESSIONS WITH $FEV_{1.0}$/FVC AS
DEPENDENT VARIABLE FOR SMOKERS

$FEV_{1.0}$/FVC = 0.631 + 0.688(OZONE)***	R^2 = 0.024
$FEV_{1.0}$/FVC = 0.816 - 3.966(CO)***	R^2 = 0.021
$FEV_{1.0}$/FVC = 0.712 - 0.520(NO2)	R^2 = 0.004
$FEV_{1.0}$/FVC = 0.757 - 4.440(NO)***	R^2 = 0.096
$FEV_{1.0}$/FVC = 0.931 - 0.004(HUMID)**	R^2 = 0.016
$FEV_{1.0}$/FVC = 0.201 + 0.007(TEMP)***	R^2 = 0.047

 **Significant at α = 0.05
***Significant at α = 0.01

TABLE 43. SIMPLE REGRESSIONS WITH $FEV_{1.0}$/FVC AS
DEPENDENT VARIABLE FOR NONSMOKERS

$FEV_{1.0}$/FVC = 0.670 + 0.288(OZONE)	R^2 = 0.004
$FEV_{1.0}$/FVC = 0.815 - 3.744(CO)***	R^2 = 0.019
$FEV_{1.0}$/FVC = 0.653 + 0.169(NO2)	R^2 = 0.001
$FEV_{1.0}$/FVC = 0.772 - 4.815(NO)***	R^2 = 0.116
$FEV_{1.0}$/FVC = 1.047 - 0.006(HUMID)***	R^2 = 0.036
$FEV_{1.0}$/FVC = 0.179 + 0.007(TEMP)***	R^2 = 0.057

***Significant at α = 0.01

summary, the single variable regressions indicate that CO, NO, and HUMIDITY are inversely related to the variable maximum $FEV_{1.0}$/maximum FVC for both smokers and nonsmokers. Variable OZONE is positively related to maximum $FEV_{1.0}$/maximum FVC, but the estimated coefficient is not statistically significant for nonsmokers.

Contingency Tables for $FEV_{1.0}$ and Air Pollution Variables

Contingency tables were constructed and χ^2 tests were applied between MAXFEV and the air pollution variables. Three categories for all variables were constructed with the transition points being one standard deviation above and below the mean with the exception of the NO variable. The two categories for NO were constructed with the division occurring at the mean. The contingency tables and computed χ^2 values are reported in Tables 44A through 44D.

The hypothesis of independence for a (3x3) table requires four degrees of freedom. The computed χ^2 must exceed 9.49 at $\alpha = 0.05$ if the hypothesis of independence is to be rejected. For the (3x2) table there are two degrees of freedom, and the computed χ^2 must exceed 5.99 at $\alpha = 0.05$ in order to reject the hypothesis of independence. As shown in the table, all of the computed χ^2 values are large enough to reject the null hypothesis. This lends support to the hypothesis of dependence or association between MAXFEV and the pollution variables OZONE, CO, NO_2, and NO for outdoor worker panel.

Linear Probability Model

A linear probability formation was estimated using the dichotomous discomfort variables as dependent variables. A different air pollution variable was used as the explanatory variable in each regression. The specifications were estimated for the entire outdoor worker panel. The regressions which were significant at $\alpha = 0.10$ or better are shown in Table 45. Then, the specifications were estimated for the smokers; the significant regressions for smokers are shown in Table 46. Finally, the specifications were estimated for the nonsmokers on the panel; the significant regressions are shown in Table 47.

For the outdoor worker panel as a whole, EYES is significantly correlated with OZONE, CO, NO_2, NO, HUMID, and TEMP. Variables NO and HUMID have estimated coefficients of negative sign. EYES is directly related to the other variables. THROAT is significantly related only to HUMID. CHEST is significantly related to OZONE and TEMP. OTHER is inversely related to NO. BREATH is directly related to OZONE and TEMP and inversely related to NO. COUGH is directly related to OZONE and TEMP and inversely related to NO_2. None of the other discomfort

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TABLE 44A. CONTINGENCY TABLE FOR MAXFEV (IN LITERS x 100)
AND OZONE FOR THE OUTDOOR WORKER PANEL

	OZONE < .015	.015 ≤ OZONE ≤ .145	.145 < OZONE	Row Total
MAXFEV < 302				
Count	.54	156	45	255
Row %	21.2	61.2	17.6	
Column %	52.9	24.1	30.2	
Total %	6.0	17.4	5.0	28.4
302 ≤ MAXFEV ≤ 452				
Count	39	412	82	533
Row %	7.3	77.3	15.4	
Column %	38.2	63.6	55.0	
Total %	4.3	45.8	9.1	59.3
MAXFEV > 452				
Count	9	80	22	111
Row %	8.1	72.1	19.8	
Column %	8.8	12.3	14.8	
Total %	1.0	8.9	2.4	12.3
Total Count	102	648	149	
Total Percent	11.3	72.1	16.6	

$\chi^2 = 37.93$

TABLE 44B. CONTINGENCY TABLE FOR MAXFEV (IN LITERS x 100) AND CO FOR THE OUTDOOR WORKER PANEL

	CO < .025	.025 ≤ CO ≤ .047	.047 < CO	Row Total
MAXFEV < 302				
Count	16	177	62	255
Row %	6.3	69.4	24.3	
Column %	12.1	29.5	37.3	
Total %	1.8	19.7	6.9	28.4
302 ≤ MAXFEV ≤ 452				
Count	91	352	84	533
Row %	18.2	66.0	15.8	
Column %	73.5	58.6	50.6	
Total %	10.8	39.2	9.3	59.3
MAXFEV > 452				
Count	19	72	20	111
Row %	17.1	64.9	18.0	
Column %	14.4	12.0	12.0	
Total %	2.1	8.0	2.2	12.3
Total Count	132	601	166	
Total Percent	14.7	66.9	18.5	

$\chi^2 = 24.43$

TABLE 44C. CONTINGENCY TABLE FOR MAXFEV (IN LITERS $\dot{x}$ 100) AND NO2 FOR THE OUTDOOR WORKER PANEL

	NO2 < .036	.036 ≤ NO2 ≤ .118	.118 < NO2	Row Total
MAXFEV < 302				
Count	16	214	25	255
Row %	6.3	83.9	9.8	
Column %	13.8	30.8	28.1	
Total %	1.8	23.8	2.8	28.4
302 ≤ MAXFEV ≤ 452				
Count	91	370	52	533
Row %	17.1	73.2	9.8	
Column %	78.4	56.2	58.4	
Total %	10.1	43.4	5.8	59.3
MAXFEV > 452				
Count	9	90	12	111
Row %	8.1	81.1	10.8	
Column %	7.8	13.0	13.5	
Total %	1.0	10.0	1.3	12.3
Total Count	116	694	89	
Total Percent	12.9	77.2	9.9	

$\chi^2 = 20.78$

TABLE 44D. CONTINGENCY TABLE FOR MAXFEV (IN LITERS x 100) AND NO FOR OUTDOOR WORKER PANEL

	NO < .02	NO ≥ .02	Row Total
MAXFEV < 302			
Count	130	125	255
Row %	51.0	49.0	
Column %	22.0	40.6	
Total %	14.5	13.9	28.4
302 ≤ MAXFEV ≤ 452			
Count	387	146	533
Row %	72.6	27.4	
Column %	65.5	47.4	
Total %	43.0	16.2	59.3
MAXFEV > 452			
Count	74	37	111
Row %	66.7	33.3	
Column %	12.5	12.0	
Total %	8.2	4.1	12.3
Total Count	591	308	
Total Percent	65.7	34.3	

$\chi^2 = 35.87$

TABLE 45.   SIMPLE LINEAR PROBABILITY REGRESSIONS
FOR THE ENTIRE OUTDOOR WORKER PANEL (N = 882)

Prob(EYES)   = -0.003 + 2.241(OZONE)*** R^2 = 0.147

Prob(EYES)   =   0.086 + 2.456(CO)** R^2 = 0.005

Prob(EYES)   =   0.139 + 0.571(NO2)* R^2 = 0.004

Prob(EYES)   =   0.230 - 2.739(NO)*** R^2 = 0.025

Prob(EYES)   =   0.468 - 0.005(HUMID)*** R^2 = 0.015

Prob(EYES)   = -0.496 + 0.009(TEMP)*** R^2 = 0.062

Prob(THROAT) =   0.299 - 0.003(HUMID)** R^2 = 0.006

Prob(CHEST)   =   0.077 + 0.872(OZONE)*** R^2 = 0.026

Prob(CHEST)   = -0.031 + 0.002(TEMP)** R^2 = 0.005

Prob(OTHER)   =   0.277 - 1.126(NO)* R^2 = 0.003

Prob(BREATH) =   0.020 + 0.840(OZONE)*** R^2 = 0.038

Prob(BREATH) =   0.104 - 0.742(NO)* R^2 = 0.003

Prob(BREATH) = -0.093 + 0.002(TEMP)*** R^2 = 0.009

Prob(COUGH)   =   0.271 + 1.008(OZONE)*** R^2 = 0.019

Prob(COUGH)   =   0.437 - 0.945(NO2)** R^2 = 0.006

Prob(COUGH)   =   0.150 + 0.003(TEMP)** R^2 = 0.004

Prob(PHLEGM) =   0.482 + 0.641(OZONE)* R^2 = 0.008

Prob(PHLEGM) =   0.786 - 6.917(CO)*** R^2 = 0.026

Prob(PHLEGM) =   0.688 - 1.673(NO2)*** R^2 = 0.018

*Significant at α = 0.10

**Significant at α = 0.05

***Significant at α = 0.01

TABLE 46. SIMPLE LINEAR PROBABILITY REGRESSIONS FOR THE SMOKERS (N = 354)

Prob(EYES)	=	0.007 + 2.458(OZONE)***	R^2 = 0.159
Prob(EYES)	=	0.268 - 3.424(NO)***	R^2 = 0.032
Prob(EYES)	=	0.652 - 0.007(HUMID)***	R^2 = 0.027
Prob(EYES)	=	-0.839 + 0.014(TEMP)***	R^2 = 0.126
Prob(THROAT)	=	0.131 + 0.617(OZONE)**	R^2 = 0.011
Prob(THROAT)	=	0.053 + 3.788(CO)***	R^2 = 0.011
Prob(CHEST)	=	0.139 + 1.181(OZONE)***	R^2 = 0.033
Prob(CHEST)	=	-0.041 + 0.004(TEMP)*	R^2 = 0.008
Prob(HEADACHE)	=	0.033 + 0.500(OZONE)**	R^2 = 0.016
Prob(HEADACHE)	=	-0.031 + 2.969(CO)**	R^2 = 0.016
Prob(NAUSEA)	=	0.134 - 0.002(HUMID)**	R^2 = 0.013
Prob(OTHER)	=	0.236 + 0.744(OZONE)**	R^2 = 0.011
Prob(BREATH)	=	0.013 + 1.651(OZONE)***	R^2 = 0.093
Prob(BREATH)	=	0.019 + 3.709(CO)**	R^2 = 0.013
Prob(BREATH)	=	0.341 + 0.007(TEMP)***	R^2 = 0.036
Prob(COUGH)	=	0.483 + 1.356(OZONE)***	R^2 = 0.033
Prob(COUGH)	=	0.733 - 1.803(NO2)**	R^2 = 0.017
Prob(COUGH)	=	0.266 + 0.005(TEMP)*	R^2 = 0.009
Prob(PHLEGM)	=	0.953 - 5.733(CO)**	R^2 = 0.021

*Significant at α = 0.10
**Significant at α = 0.05
***Significant at α = 0.01

TABLE 47. SIMPLE LINEAR PROBABILITY REGRESSIONS
FOR THE NONSMOKERS (N = 528)

Prob(EYES)	=	-0.009 + 2.087(OZONE)***	R^2 = 0.139
Prob(EYES)	=	0.059 + 2.577(CO)*	R^2 = 0.007
Prob(EYES)	=	0.112 + 0.661(NO2)*	R^2 = 0.006
Prob(EYES)	=	0.203 - 2.264(NO)***	R^2 = 0.020
Prob(EYES)	=	0.368 - 0.004(HUMID)**	R^2 = 0.009
Prob(EYES)	=	-0.309 + 0.006(TEMP)***	R^2 = 0.038
Prob(THROAT)	=	0.313 - 0.004(HUMID)***	R^2 = 0.014
Prob(CHEST)	=	0.038 + 0.640(OZONE)***	R^2 = 0.021
Prob(HEADACHE)	=	0.076 - 0.289(OZONE)*	R^2 = 0.007
Prob(NAUSEA)	=	-0.036 + 0.001(HUMID)*	R^2 = 0.006
Prob(BREATH)	=	0.026 + 0.274(OZONE)*	R^2 = 0.007
Prob(COUGH)	=	0.133 + 0.710(OZONE)***	R^2 = 0.014
Prob(PHELGM)	=	0.167 + 1.227(OZONE)***	R^2 = 0.036

*Significant at α = 0.10
**Significant at α = 0.05
***Significant at α = 0.01

symptom variables are significantly related to any of the air pollution or weather variables for the panel as a whole.

EYES is not significantly related to CO or NO_2 for the smokers in the panel. However, the relationship of eye discomfort with OZONE, NO, HUMID, and TEMP appears to be stronger for smokers than for nonsmokers since the magnitude of the estimated slope coefficients is larger. THROAT is significantly related to OZONE and CO for the smokers. CHEST is directly related to OZONE and TEMP as with the whole panel. HEADACHE is directly related to OZONE and CO. OTHER is significantly related to OZONE. BREATH is strongly related to OZONE, CO, and TEMP. COUGH is directly related to OZONE and TEMP and inversely related to NO_2. PHLEGM is inversely related to CO for the smokers.

There are fewer significant linear probability specifications for the nonsmokers in the panel. However, EYES is again significantly related to all of the air pollution variables for the nonsmokers. THROAT remains inversely related to HUMID and not significantly related to the other air pollution and weather variables. CHEST is no longer significantly related to TEMP, but chest discomfort remains directly related to OZONE. HEADACHE is now inversely related to OZONE, but the level of statistical significance is not high. NAUSEA is now directly related to HUMID, but the relation is not strong. BREATH is no longer significantly related to NO or TEMP, but remains directly related to OZONE. Similarly, COUGH remains directly related to OZONE, but is no longer significantly related to NO_2 or TEMP. PHLEGM is related to OZONE, but not to CO or NO_2 for the non-smokers.

SELECTED MULTIVARIATE LINEAR PROBABILITY REGRESSIONS

The form of the multivariate linear probability model is

$$\theta_i = \text{Prob}(Y = 1) = \beta_o + \sum_{j=1}^{k} \beta_j X_{ij} \quad ; \quad i = 1,\ldots,N.$$

This model was introduced and discussed in the analysis of the asthma panel data. The predicted value of the dependent variable, the qualitative discomfort symptom, can be interpreted as the probability that the discomfort symptom is present given values of the explanatory variable. Six of the discomfort symptom variables were used as dependent variables: EYES, THROAT, CHEST, BREATH, and PHLEGM. They were chosen because they were most frequently related to at least some of the air

pollution variables. All of the air pollution variables were used as explanatory variables. The data were restricted to those outdoor workers who reported not having a cold and not taking medication. The results are reported in Table 48.

One of the regressions, that for THROAT, resulted in a total F which indicated that none of the estimated coefficients were significantly different from zero. All of the other regressions resulted in at least one explanatory variable whose coefficient was statistically significant at $\alpha = 0.05$ or better.

The EYES regression resulted in OZONE as the only statistically significant explanatory variable. None of the other air pollution variables were significant in reducing the variation in eye discomfort. The estimated equation indicates that when OZONE increases by 0.10, the probability of experiencing eye discomfort increases by more than 0.20, i.e., by more than 20 percent.

CHEST and BREATH are significantly related to OZONE and HUMID in the multivariate regressions. The estimated coefficients are positive. When the level of OZONE increases by 0.10, the estimated probability of experiencing chest discomfort and shortness of breath increases by about 0.12 or 12 percent. COUGH is significantly and positively related to OZONE, NO, and HUMID, and COUGH is inversely related to CO. When OZONE increases by 0.10, the probability of having a cough increases by almost 0.03 or 3 percent. An increase in NO of 0.01 is estimated to increase the probability of having a cough by almost 0.01 or 1 percent. An increase in CO of 0.10 is estimated to cause a reduction in the probability of having a cough by about 0.10 or 10 percent. PHLEGM is significantly related to OZONE and CO only. The estimate indicated a 0.10 increase in OZONE is estimated to cause an increase in the probability of having phlegm by about 0.15 or 15 percent. when CO increases by 0.01, the probability of having phlegm is reduced by about 0.14 or 14 percent.

In general, the subjects in the outdoor worker panel show more sensitivity in reporting discomfort symptoms than demonstrated by the asthma, athlete, or bronchitis panels. This may be caused by a more direct exposure to the environment or to the greater physical stress of working prior to being tested.

Eye discomfort was again the symptom that was reported most consistently. But the outdoor workers also exhibited significant response to the air pollution variables in reporting throat discomfort, chest discomfort, shortness of breath, cough, and phlegm. When multivariate linear probability specifications were estimated, throat discomfort was not significantly related to any of the air pollution variables. Eye discomfort, chest discomfort, and shortness of breath were significantly related

TABLE 48. MULTIVARIATE LINEAR PROBABILITY FUNCTIONS FOR EYE, THROAT, AND CHEST DISCOMFORT, SHORTNESS OF BREATH, COUGH, AND PHLEGM--ALL OUTDOOR WORKER PANELISTS (STANDRAD ERRORS IN PARENTHESES)

Prob(EYES)   = -0.548 + 2.185(OZONE)** - 1.390(CO)   + 0.235(NO2)
                        (0.532)   (3.584)   (0.862)

                      - 0.037(NO)   + 0.0025(HUMID) + 0.0064(TEMP)
                        (2.396)   (0.0037)   (0.0039)

        R^2 = 0.18, N = 281, F = 9.98

Prob(THROAT) = 0.356 + 0.738(OZONE)   - 3.684(CO)   + 0.986(NO2)
                        (0.488)   (3.290)   (0.791)

                      - 2.209(NO)   + 0.0003(HUMID) - 0.0028(TEMP)
                        (2.200)   (0.0034)   (0.0036)

        R^2 = 0.02, N = 281, F = 0.75

Prob(CHEST) = -0.962 + 1.252(OZONE)** - 1.414(CO)   + 0.598(NO2)
                        (0.493)   (3.320)   (0.799)

                      + 1.866(NO)   + 0.0080(HUMID)** + 0.0068(TEMP)
                        (2.220)   (0.0035)   (0.0036)

        R^2 = 0.08, N = 281, F = 3.76

Prob(BREATH) = -0.630 + 1.186(OZONE)** - 1.899(CO)   + 0.850(NO2)
                        (0.422)   (2.841)   (0.683)

                      - 1.278(NO)   + 0.0069(HUMID)** + 0.0033(TEMP)
                        (1.899)   (0.0030)   (0.0031)

        R^2 = 0.08, N = 281, F = 4.01

Prob(COUGH) = -0.078 + 2.552(OZONE)** - 9.748(CO)**   - 0.519(NO2)
                        (0.617)   (4.158)   (0.999)

                      + 7.675(NO)   + 0.0092(HUMID)** + 0.0037(TEMP)
                        (2.780)   (0.0043)   (0.0046)

        R^2 = 0.12, N = 281, F = 5.99

Prob(PHLEGM) = 0.164 + 1.497(OZONE)** - 13.941(CO)**   + 0.264(NO2)
                        (0.687)   (4.630)   (1.114)

                      + 5.511(NO)   + 0.0061(HUMID) + 0.0031(TEMP)
                        (3.096)   (0.0048)   (0.0051)

        R^2 = 0.07, N = 281, F = 3.37

**Significant at α = 0.05

to only one air pollution variable, OZONE. However, cough was directly related to both OZONE and NO and inversely related to CO. Phlegm was directly related to OZONE and inversely related to CO in the multiple regression. Relationships between the discomfort symptoms and the air pollution variables were tested again utilizing a more appropriate sigmoid probability function in the analysis of the proportions of respondents reporting each discomfort symptom by date. The results of the tests are discussed later in Section 8.

BETWEEN GROUP DIFFERENCES

The outdoor worker panel was divided into four sub-panels prior to the daily surveillance. The absolute frequency and relative frequency of observations for each of the four sub-panels are given in Table 49. Each sub-panel was tested during different two-week periods. Differences between groups is a potential source of variation which was examined. As in the analysis of the asthma panel, the procedure was to check for small sample bias or self-selection bias; i.e., to determine if there were unmeasured and unexpected differences between the groups that cannot be controlled using appropriate statistical methods. Under this procedure, if any differences encountered can be controlled, then the four sub-panels can be pooled and analyzed together.

TABLE 49. BREAKDOWN OF THE FOUR OUTDOOR WORKER SUB-PANELS BY ABSOLUTE AND RELATIVE FREQUENCY OF OBSERVATIONS

Sub-Panel	Absolute Frequency	Relative Frequency (%)
1	209	23.2%
2	275	30.6
3	226	25.1
4	189	21.0
	899	100.0%

Difference in Means Tests

The following paragraphs present the results of difference in means tests for the four sub-panels. Three variables were

tested. The first variable tested was MAXFEV which was unadjusted for age, height, or other explanatory variables. However, the sample size was reduced by examining only those panelists who reported not having a cold and not taking medication. In addition, missing observations for the MAXFEV variable necessitated omission of those observations.

The second variable tested was the difference between actual recorded $FEV_{1.0}$ and predicted $FEV_{1.0}$ where

$$\text{Predicted } FEV_{1.0} = -214.60 - 4.089(\text{AGE})$$

$$+11.110(\text{HEIGHT}) - 32.715(\text{SMOKE})$$

and where the coefficient of determination for predicted $FEV_{1.0}$ was $R^2 = 0.33$. The coefficients of all three of the explanatory variables for this equation were significant at $\alpha = 0.01$. The $FEV_{1.0}$ difference variable was then compiled as

$$\text{DIFFEV} = \text{MAXFEV} - \text{Predicted } FEV_{1.0}$$

Variable DIFFEV controls for age, height, and whether or not the panelist was a smoker.

The third variable tested was maximum $FEV_{1.0}$ divided by maximum FVC. This variable, $FEV_{1.0}/\text{FVC}$, measured the proportion of MAXFEV with respect to MAXFEV since MAXFVC should vary directly with age, height, and other unmeasured physical characteristics.

For all three of these variables, MAXFEV, DIFFEV, and $FEV_{1.0}/\text{FVC}$, a F-test of sample variances was performed between pairs. This was necessary to choose the appropriate t-test to examine the differences in means between all four sub-panels.

Between Group Differences in MAXFEV

The sample means and sample standard deviations of MAXFEV for the four groups are given in Table 50. The results of the F-tests are reported in Table 51. The level of significance chosen was $\alpha = 0.10$. A two-tailed test was applied and the results indicate a rejection of the null hypothesis of equal variance of MAXFEV between Sub-Panel 1 and Sub-Panel 2, Sub-Panel 1 and Sub-Panel 3, Sub-Panel 2 and Sub-Panel 4, and Sub-Panel 3 and Sub-Panel 4. The hypothesis of equal variance of MAXFEV cannot be rejected at $\alpha = 0.10$ between Sub-Panel 1 and Sub-Panel 4 nor between Sub-Panel 2 and Sub-Panel 3. Since the results tend to favor the hypothesis of unequal variance, the conservative strategy of using separate variance estimates was applied in the performance of the t-tests.

TABLE 50.   SAMPLE MEANS AND STANDARD DEVIATIONS
FOR MAXFEV OF THE FOUR OUTDOOR WORKER SUB-PANELS

Sub-Panel	N	$\bar{X}$	S
1	131	382.14	96.11
2	138	373.19	60.00
3	179	396.70	53.88
4	126	341.67	86.78

TABLE 51.   DIFFERENCES IN MAXFEV VARIANCES TEST ON
OUTDOOR WORKER SUB-PANELS

H_o	F	$\alpha/2$	Significant at $\alpha = 0.10$	Decision on H_o
$\sigma_1 = \sigma_2$	2.57	0.00	yes	reject
$\sigma_1 = \sigma_3$	3.18	0.00	yes	reject
$\sigma_1 = \sigma_4$	1.23	0.12	no	do not reject
$\sigma_2 = \sigma_3$	1.24	0.09	no	do not reject
$\sigma_2 = \sigma_4$	2.09	0.00	Yes	reject
$\sigma_3 = \sigma_4$	2.59	0.00	yes	reject

The results of the t-tests on the mean MAXFEV between groups are reported in Table 52. The results indicate that the null hypothesis $\mu_1 = \mu_2$ and the null $\mu_1 = \mu_3$ cannot be rejected at $\alpha = 0.05$. However, the hypothesized equality between the means of the remaining groups is rejected at $\alpha = 0.05$. Some of the results are contradictory e.g., $\mu_1 = \mu_2$ and $\mu_1 = \mu_3$, which

TABLE 52. DIFFERENCE IN MAXFEV MEANS TEST ON OUTDOOR WORKER
SUB-PANELS USING SEPARATE VARIANCE ESTIMATES

H_o	t	$\alpha/2$	Significant at $\alpha = 0.05$	Decision on H_o
$\mu_1 = \mu_2$	0.91	0.182	no	do not reject
$\mu_1 = \mu_3$	-1.56	0.060	no	do not reject
$\mu_1 = \mu_4$	3.55	0.000	yes	reject
$\mu_2 = \mu_3$	-3.62	0.000	yes	reject
$\mu_2 = \mu_4$	3.40	0.001	yes	reject
$\mu_3 = \mu_4$	6.31	0.000	yes	reject

implies that $\mu_2 = \mu_3$, but this latter hypothesis is rejected.
Nevertheless, this preliminary investigation does indicate a
difference between Sub-Panel 4 and the other three sub-panels.

Between-Group Difference in DIFFEV

The above analysis was replicated for the $FEV_{1.0}$ difference
variable, DIFFEV. The general hypothesis tested was that the
between-group differences in MAXFEV are due to age, height, and
smoking. The F-tests results of the hypothesis of no difference
in the variance of DIFFEV between each group are reported in
Table 53. The hypothesis that $\sigma_1 = \sigma_2$ and the hypothesis that
$\sigma_3 = \sigma_4$ cannot be rejected at $\alpha = 0.10$. However, the other
pairs are rejected. A conservative strategy again leads to the
utilization of separate variance estimates in the performance of
the t-tests of differences between the group means. The results
of the t-tests for DIFFEV are reported in Table 54. Again, the
results are mixed. It is not possible to reject the hypothesis
that $\mu_1 = \mu_2$, $\mu_1 = \mu_4$, and $\mu_2 = \mu_4$. But the hypothesis that
$\mu_1 = \mu_3$, $\mu_2 = \mu_3$, and $\mu_3 = \mu_4$ are rejected at the $\alpha = 0.05$ level
of significance. These tests support an argument that Sub-Panel
3 is distinct from the other three groups, while Sub-Panel 1,
Sub-Panel 2, and Sub-Panel 4 are indistinguishable once age,
height, and smoking are used to control for between-group dif-
ferences in MAXFEV.

TABLE 53. DIFFERENCES IN DIFFEV VARIANCES TEST ON OUTDOOR
WORKER SUB-PANELS

H_o	F	$\alpha/2$	Significant at $\alpha = 0.10$	Decision on H_o
$\sigma_1 = \sigma_2$	1.18	0.136	no	do not reject
$\sigma_1 = \sigma_3$	1.73	0.001	yes	reject
$\sigma_1 = \sigma_4$	1.92	0.001	yes	reject
$\sigma_2 = \sigma_3$	1.47	0.004	yes	reject
$\sigma_2 = \sigma_4$	1.62	0.002	yes	reject
$\sigma_3 = \sigma_4$	1.11	0.260	no	do not reject

TABLE 54. DIFFERENCE IN DIFFEV MEANS TEST ON OUTDOOR
WORKER SUB-PANELS

H_o	t	$\alpha/2$	Significant at $\alpha = 0.05$	Decision on H_o
$\mu_1 = \mu_2$	0.47	0.314	no	do not reject
$\mu_1 = \mu_3$	-2.39	0.018	yes	reject
$\mu_1 = \mu_4$	-0.40	0.343	no	do not reject
$\mu_2 = \mu_3$	-3.19	0.001	yes	reject
$\mu_2 = \mu_4$	-0.98	0.165	no	do not reject
$\mu_3 = \mu_4$	2.30	0.011	yes	reject

The difference in variances and difference in means tests were replicated for the $FEV_{1.0}/FVC$ variable. The results are reported in Table 55 and Table 56. As with the $FEV_{1.0}$ difference variable, the hypotheses that $\sigma_1 = \sigma_2$ and $\sigma_3 = \sigma_4$ cannot be rejected, but the statistical inference is that the other pairs of variances are not equal. Therefore, the separate variance estimates were utilized in the t-tests of differences between means of the groups for the variable $FEV_{1.0}/FVC$.

The t-tests do not infer rejection of the hypotheses that $\mu_1 = \mu_2$ and $\mu_1 = \mu_4$. The remaining pairs of means are rejected, being equal at $\alpha = 0.05$. However, the hypothesis that $\mu_2 = \mu_4$ cannot be rejected at the $\alpha = 0.01$ level of significance. Therefore, the results tend to support the conclusion that Sub-Panel 3 is the only sub-panel that is statistically different from the other three sub-panels. But the evidence is not strong based on the results of the DIFFEV or $FEV_{1.0}/FVC$ analyses.

Difference Between Nonsmokers and Smokers

Difference in variances and means tests were also performed between nonsmokers and smokers within the outdoor worker panel. Again, the sample was restricted to panelists not having a cold and not taking medication. The results are reported in Table 57. The variances of MAXFEV between smokers and nonsmokers cannot be rejected as being significantly different from each other at a level of significance of $\alpha = 0.10$, but the means of MAXFEV between smokers and nonsmokers are different at a level of significance greater than $\alpha = 0.05$. For the variable MAXFVC, the statistical inference is that both variances and means are different from smokers and nonsmokers. The same conclusion holds for the variable $FEV_{1.0}/FVC$. The $FEV_{1.0}$ difference variable, DIFFEV, however, does not have statistically different means for smokers and nonsmokers at the $\alpha = 0.05$ level. This result is reasonable since DIFFEV was created using a dependent variable which controlled for smoking.

In summary, the comparison of MAXFEV, MAXFVC, and $FEV_{1.0}/FVC$ between smokers and nonsmokers indicates that there is a significant difference. Smokers have lower recorded MAXFEV, MAXFVC, and $FEV_{1.0}/FVC$ scores than nonsmokers. This further demonstrates the importance of treating the two groups separately or of controlling for the influence of smoking in the analyses of the outdoor worker panel.

TABLE 55. DIFFERENCE IN FEV$_{1.0}$/FVC VARIANCE TEST ON OUTDOOR WORKER SUB-PANELS

H_O	F	$\alpha/2$	Significant at $\alpha = 0.10$	Decision on H_O
$\sigma_1 = \sigma_2$	1.08	0.302	no	do not reject
$\sigma_1 = \sigma_3$	1.35	0.023	yes	reject
$\sigma_1 = \sigma_4$	1.45	0.012	yes	reject
$\sigma_2 = \sigma_3$	1.46	0.005	yes	reject
$\sigma_2 = \sigma_4$	1.57	0.003	yes	reject
$\sigma_3 = \sigma_4$	1.07	0.326	no	do not reject

TABLE 56. DIFFERENCE IN FEV$_{1.0}$/FVC MEANS TEST ON OUTDOOR WORKER SUB-PANELS

H_O	t	$\alpha/2$	Significant at $\alpha = 0.05$	Decision on H_O
$\mu_1 = \mu_2$	1.31	0.096	no	do not reject
$\mu_1 = \mu_3$	3.04	0.002	yes	reject
$\mu_1 = \mu_4$	-0.78	0.218	no	do not reject
$\mu_2 = \mu_3$	-4.55	0.000	yes	reject
$\mu_2 = \mu_4$	-2.17	0.016	yes	reject
$\mu_3 = \mu_4$	2.36	0.010	yes	reject

TABLE 57. DIFFERENCE IN VARIANCES AND MEANS TESTS BETWEEN NONSMOKERS (NS)
AND SMOKERS (S) ON OUTDOOR WORKER SUB-PANELS

Variable	Sub-Panel (N)	$\bar{X}$	S	F	Significant at $\alpha = 0.10$	t	Significant at $\alpha = 0.05$
MAXFEV (In Liters x 100)	NS(348)	389.74	75.70	1.06	no	5.60	yes
	S(226)	353.94	73.61				
MAXFVC (In Liters x 100)	NS(420)	473.39	89.61	1.31	yes	2.71	yes
	S(267)	457.69	78.32				
DIFFEV (In Liters x 100)	NS(348)	0.0002	60.10	1.24	yes	-0.00	no
	S(226)	0.0002	66.89				
FEV/FVC	NS(348)	0.829	0.11	1.46	yes	4.44	yes
	S(226)	0.781	0.13				

DISCOMFORT SYMPTOMS ANALYZED BY DATE OF MEASUREMENT

Daily surveillance of the outdoor worker panel was conducted on 54 different dates. On each date, the proportion of the panelists reporting each discomfort symptom was calculated. The average levels of OZONE, CO, NO_2, NO, HUMID, and TEMP were computed for each date also. The average levels of air pollution were then related to the proportion of panelists reporting each discomfort symptom on each date. This was done using two techniques, simple linear regressions, and selected multivariate regressions.

Simple Linear Regressions

Let f_g denote the proportion of panelists reporting a discomfort symptom for date $g = 1,...,G$. Let $\bar{X}_g$ denote the average level of an air pollution variable on date g. Then a linear probability specification using the proportions and averages is:

$$f_g = \alpha_o + \alpha_1 \bar{X}_g \quad ; \quad g = 1,...,G.$$

In applying this specification, each of the discomfort proportions were used as the dependent variable and each of the air pollution variables were used as the explanatory variable. The simple linear regressions which are significant at $\alpha = 0.10$ or better are shown in Table 58.

EYES is significantly related to OZONE, CO, NO, HUMID, and TEMP. THROAT is significantly related to OZONE, NO_2, and HUMID. CHEST is significantly related to OZONE, NO, and TEMP. HEADACHE is significantly related only to CO. BREATH is significantly related to OZONE, NO, and TEMP. COUGH is significantly related to OZONE and TEMP. PHLEGM is significantly related only to OZONE, but the relation is not strong at $\alpha = 0.10$. Therefore, PHLEGM is omitted from further analysis.

Single variable LOGIT regressions were estimated for EYES, THROAT, CHEST, HEADACHE, BREATH, and COUGH. The significant regressions are shown in Table 59. The LOGIT transformation is:

$$\ln\left[\frac{f_g}{1-f_g}\right] = \beta_o + \beta_1 \bar{X}_g \quad ; \quad g = 1,...,G$$

where $\bar{X}_g$ is the mean of the explanatory variable for date g and f_g is the proportion of panelists reporting symptoms on date g. The specification is sigmoid in shape; hence, it is consistent with a probability specification.

TABLE 58. SIGNIFICANT SIMPLE REGRESSIONS OF DISCOMFORT
SYMPTOM PROPORTIONS

Proportion(EYES)	=	$-0.043 + 2.728$(OZONE)***	$R^2 = 0.584$
Proportion(EYES)	=	$-0.018 + 5.925$(CO)**	$R^2 = 0.097$
Proportion(EYES)	=	$0.241 - 3.346$(NO)*	$R^2 = 0.041$
Proportion(EYES)	=	$0.459 - 0.005$(HUMID)*	$R^2 = 0.036$
Proportion(EYES)	=	$-0.533 + 0.010$(TEMP)***	$R^2 = 0.201$
Proportion(THROAT)	=	$0.103 + 0.360$(OZONE)**	$R^2 = 0.056$
Proportion(THROAT)	=	$0.104 + 0.370$(NO2)*	$R^2 = 0.037$
Proportion(THROAT)	=	$0.319 - 0.003$(HUMID)**	$R^2 = 0.084$
Proportion(CHEST)	=	$0.066 + 1.006$(OZONE)***	$R^2 = 0.233$
Proportion(CHEST)	=	$0.179 - 1.777$(NO)*	$R^2 = 0.034$
Proportion(CHEST)	=	$-0.075 + 0.003$(TEMP)**	$R^2 = 0.058$
Proportion(HEADACHE)	=	$0.011 + 1.496$(CO)**	$R^2 = 0.060$
Proportion(BREATH)	=	$-0.009 + 1.182$(OZONE)***	$R^2 = 0.352$
Proportion(BREATH)	=	$0.124 - 2.067$(NO)*	$R^2 = 0.050$
Proportion(BREATH)	=	$-0.156 + 0.003$(TEMP)**	$R^2 = 0.075$
Proportion(COUGH)	=	$0.260 + 0.864$(OZONE)**	$R^2 = 0.096$
Proportion(COUGH)	=	$0.026 + 0.004$(TEMP)**	$R^2 = 0.060$
Proportion(PHLEGM)	=	$0.385 + 0.960$(OZONE)*	$R^2 = 0.035$

*Significant at $\alpha = 0.10$
**Significant at $\alpha = 0.05$
***Significant at $\alpha = 0.01$

TABLE 59. SIGNIFICANT LOGIT REGRESSIONS OF DISCOMFORT
SYMPTOM PROBABILITIES

$$\ln \left\{ \frac{\text{Prob(EYES)}}{1 - \text{Prob(EYES)}} \right\} = -5.475 + 30.491(\text{OZONE})*** \quad R^2 = 0.471$$

$$\ln \left\{ \frac{\text{Prob(EYES)}}{1 - \text{Prob(EYES)}} \right\} = -5.756 + 81.857(\text{CO})*** \quad R^2 = 0.119$$

$$\ln \left\{ \frac{\text{Prob(EYES)}}{1 - \text{Prob(EYES)}} \right\} = 2.364 + -0.092(\text{HUMID})*** \quad R^2 = 0.123$$

$$\ln \left\{ \frac{\text{Prob(EYES)}}{1 - \text{Prob(EYES)}} \right\} = -13.214 + 0.139(\text{TEMP})*** \quad R^2 = 0.266$$

$$\ln \left\{ \frac{\text{Prob(BREATH)}}{1 - \text{Prob(BREATH)}} \right\} = -5.482 + 16.322(\text{OZONE})*** \quad R^2 = 0.150$$

$$\ln \left\{ \frac{\text{Prob(BREATH)}}{1 - \text{Prob(BREATH)}} \right\} = -9.329 + 0.070(\text{TEMP})** \quad R^2 = 0.076$$

**Significant at $\alpha = 0.05$

***Significant at $\alpha = 0.01$

None of the LOGIT regressions for THROAT, CHEST, HEADACHE, or COUGH were statistically significant. EYES remains statistically significantly related to OZONE, CO, HUMID, and TEMP, but it is no longer significantly related to NO. BREATH remains significantly related to OZONE and TEMP, but is no longer significantly related to NO.

Selected Multivariate Regressions

Seven of the discomfort symptom variables were chosen for multivariate regression analysis. The dependent variable was the proportion of panelists reporting a discomfort symptom or the LOGIT transformation of that proportion. The explanatory variables were the average levels of each of the air pollution variables on the date of testing.

Initially, seven linear probability specifications were estimated. The four specifications using EYES, BREATH, CHEST, and COUGH demonstrated some statistical significance. The results are reported in Table 60. Three regression estimates, those for THROAT, HEADACHE, and PHLEGM, are not reported since none of the explanatory variables had estimated coefficients statistically different from zero. The variable measuring OZONE was statistically significant in the regression for EYES, BREATH, and CHEST.

Secondly, the LOGIT transformation of each of the proportions--EYES, BREATH, CHEST, and COUGH--were regressed on the air pollution variables. The results are reported in Table 61. In the first regression using the LOGIT of EYES, OZONE, and TEMP were statistically significant. In the second regression using BREATH, OZONE, and NO_2 were significant. In the third using CHEST, none of the explanatory variables were significant. In the fourth regression, only CO contributed significantly in explaining COUGH.

Since the LOGIT transformation is subject to heteroscedasticity due to unique size groups in computing the proportions, a correction technique was applied. The transformation is to utilize

$$\ln \left\{ \frac{n_g \cdot f_g + 0.5}{n_g (1 - f_g) + 0.5} \right\} = \beta_o + \sum_{j=1}^{k} \beta_j \bar{X}_{ij} \quad ; \ g = 1, \ldots, G$$

in place of

$$\ln \left\{ \frac{f_g}{1 - f_g} \right\} = \beta_o + \sum_{j=1}^{k} \beta_j \bar{X}_{ig} \quad ; \ g = 1, \ldots, G$$

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TABLE 60. MULTIVARIATE REGRESSIONS OF PROPORTIONS OF
DISCOMFORT SYMPTOMS
(STANDARD ERRORS IN PARENTHESES)

Explanatory Variable	Dependent Variable			
	EYES	BREATH	CHEST	COUGH
CONSTANT	-0.273	-0.130	-0.036	-0.062
OZONE	2.494** (0.522)	1.341** (0.354)	1.219** (0.416)	0.094 (0.591)
CO	1.809 (3.000)	0.023 (2.035)	-1.573 (2.393)	-1.675 (3.397)
NO2	-0.098 (0.604)	-0.477 (0.410)	0.042 (0.482)	-0.352 (0.684)
NO	1.228 (2.198)	0.828 (1.491)	0.705 (1.754)	1.226 (2.490)
HUMID	-0.0003 (0.0025)	0.0018 (0.0017)	0.0018 (0.0020)	0.0029 (0.0028)
TEMP	0.0026 (0.0030)	0.0003 (0.0020)	0.0003 (0.0024)	0.0028 (0.0034)
R^2	0.602	0.412	0.257	0.160
F	11.832	5.488	2.714	1.491
D.W.	1.785	1.278	1.408	0.981

**Significant at $\alpha = 0.05$

Note: N = 54

TABLE 61. MULTIVARIATE REGRESSIONS OF LOGIT OF
DISCOMFORT SYMPTOMS
(STANDARD ERRORS IN PARENTHESES)

Explanatory Variable	Dependent Variable			
	EYES	BREATH	CHEST	COUGH
CONSTANT	-12.804	-10.968	-3.823	-6.119
OZONE	17.111** (6.724)	16.831** (8.120)	10.952 (8.553)	-3.261 (4.895)
CO	61.013 (38.679)	17.443 (46.709)	-4.995 (49.198)	59.666** (28.157)
NO2	6.679 (7.793)	-21.322** (9.228)	-0.608 (36.051)	-9.430 (20.633)
NO	-23.337 (28.343)	32.110 (34.228)	6.876 (36.051)	-0.869 (20.633)
HUMID	-0.0359** (0.0385)	0.0499 (0.0464)	-0.0072 (0.0489)	0.0462 (0.0280)
R^2	0.572	0.307	0.059	0.147
F	10.488	3.471	0.496	1.346
D.W.	1.802	1.700	1.250	1.390

**Significant at $\alpha = 0.05$

Note: N = 54

where f_g is the proportion in group g and n_g is the number of cases in group g used to compute the proportion. This correction helps the small sample properties of the estimation process, but has no effect on the large sample properties. The correction yields a variance of the error which is normally distributed with zero mean. Therefore, application of the t-tests do not rely on the asymptotic properties of the estimators.

The results of the LOGIT regressions corrected for heteroscedasticity are reported in Table 62. The regressions using CHEST and COUGH do not yield any estimated relationships with the air pollution variables which are statistically significant. In the two remaining regressions, that for EYES and BREATH, only OZONE demonstrates a statistically significant relationship.

Summary of the Analysis by Date

Single linear probability regressions of each discomfort symptom with each of the air pollution variables resulted in several statistically significant associations. The proportion of panelists reporting eye discomfort was significantly correlated with OZONE, CO, NO, HUMID, and TEMP which were measures of the average levels of the respective air pollution and weather data on the date of testing. Throat discomfort was significantly correlated with OZONE, NO_2, and HUMID. Chest discomfort was significantly correlated with OZONE, NO, and TEMP. The proportion of panelists reporting headache was correlated significantly only with CO, while PHLEGM showed weak statistical correlation with OZONE. Shortness of breath was correlated significantly with OZONE, NO, and TEMP. The proportion of panelists reporting cough was correlated significantly with OZONE and TEMP. Simple LOGIT transformation of the proportions resulted in significant correlations only between eye discomfort and the variables OZONE, CO, HUMID, and TEMP; and between shortness of breath and OZONE and TEMP.

Multivariate regression was then applied to the proportion of the discomfort symptoms and the logit transformation of the proportions. A correction for heteroscedasticity was applied to the LOGIT specification. Only eye discomfort and shortness of breath generated consistently significant estimates. And only OZONE remained statistically significant as an explanatory variable. It is possible, however, that multicollinearity between the explanatory variables may account for the seeming lack of influence between the discomfort symptoms and the air pollution variables. But no collinearity was readily apparent.

MULTIVARIATE ANALYSIS OF MAXFEV

As in the analysis of the asthma panel, two multivariate regression models were used to explain variations in MAXFEV, while controlling for differences between individuals. An

TABLE 62.   MULTIVARIATE LOGIT REGRESSIONS CORRECTED
FOR HETEROSCEDASTICITY: OUTDOOR WORKERS
(STANDARD ERRORS IN PARENTHESES)

Explanatory Variable	Dependent Variable			
	EYES	BREATH	CHEST	COUGH
CONSTANT	-0.401	-0.294	-0.107	-0.076
OZONE	1.652** (0.390)	0.726** (0.264)	0.516 (0.286)	0.458 (0.394)
CO	2.695 (2.245)	1.063 (1.519)	0.246 (1.644)	-0.303 (2.265)
NO2	-0.121 (0.452)	-0.511 (0.306)	-0.029 (0.331)	-0.151 (0.456)
NO	0.999 (1.645)	0.705 (1.114)	-0.021 (1.205)	-0.015 (1.660)
HUMID	0.0006 (0.0019)	0.0020 (0.0013)	0.0012 (1.2046)	0.0013 (0.0019)
TEMP	0.0029 (0.0022)	0.0017 (0.0015)	0.0006 (0.0016)	0.0019 (0.0022)
R^2	0.587	0.377	0.166	0.121
F	11.125	4.732	1.558	1.081
D.W.	2.097	1.576	1.190	1.272

**Significant at $\alpha = 0.05$

Note: N = 54

extension of this analysis in which the air pollution variables are lagged concludes the discussion of the outdoor worker panel.

The Hasselblad Model

The Hasselblad model utilizes dummy variables to control for differences between individuals. The dependent variable is MAXFEV. The form of the model is described in Section 7. Since the model controls for differences between individuals, it is not appropriate to include variables such as age, height, the presence of a cold, or smoking.

It was not possible to use the entire outdoor worker panel in this analysis because the number of explanatory variables was too large for the regression program used. The maximum number of individuals possible for inclusion was 60. Therefore, the Hasselblad specification used the 494 observations on the first 60 individuals in the panel. This resulted in 59 P_{mj} variables named P1 to P59. Variable X_{1j} was named DINV which stands for day-inverse, so DINV = $1/k$. The other explanatory variables were OZONE, CO, NO_2, and NO.

The regression is shown in Table 63. The estimated coefficients for the dummy variables P_{mj} are not reported as they only control for differences between individuals in order to isolate the effects of air pollution. It should be noted that many of the dummy variables are statistically significant. The $R^2 = 0.95$ indicates that 95 percent of the variation in the dependent variable has been explained by regression. The total F indicates rejection of a hypothesis that all coefficients are simultaneously zero. Apart from the dummy variables, none of the other explanatory variables are statistically significant.

The primary conclusion must be that the variables which capture individual differences explain a large portion of the variance in the dependent variable and that there is very little variation left to be explained by the air pollution variables. Therefore, MAXFEV was not statistically sensitive to the levels of air pollution measured during daily surveillance of the outdoor worker panel.

Standard Multivariate Regression of MAXFEV and $FEV_{1.0}/FVC$

The first four multivariate regression specifications estimated for the outdoor worker panel utilized MAXFEV and $FEV_{1.0}/FVC$ as dependent variables. Each dependent variable was used separately for smokers and nonsmokers. The results are reported in Table 64. When MAXFEV was the dependent variable, AGE and HEIGHT were included as explanatory variables to control for individual differences. Use of $FEV_{1.0}/FVC$ as the dependent

TABLE 63. HASSELBLAD REGRESSION FOR MAXFEV WITH AIR
POLLUTION VARIABLES (USING DATA FROM 60 INDIVIDUALS IN
THE OUTDOOR WORKER PANEL)

$R^2 = 0.95$, $N = 494$, Total $F = 129.7$, D.W. $= 1.87$

$$\text{MAXFEV} = -1,694.02$$

$$+ \sum_{m=1}^{59} \beta_m P_{mj}$$

$$- 40.057 \, (\text{DAYINV})$$

$$- 10.229 \, (\text{OZONE})$$

$$- 195.790 \, (\text{CO})$$

$$+ 35.815 \, (\text{NO2})$$

$$- 56.303 \, (\text{NO})$$

Note: The estimated coefficients for the dummy variables
P_{mj} are not reported as they only control for dif-
ferences between individuals so that the effects of
air pollution variables may be isolated.

TABLE 64. MULTIVARIATE REGRESSIONS FOR MAXFEV AND $FEV_{1.0}$/FVC--SMOKERS AND NONSMOKERS IN OUTDOOR WORKER PANEL (STANDARD ERRORS IN PARENTHESES)

Variable	MAXFEV, Smokers	MAXFEV, Nonsmokers	$FEV_{1.0}$/FVC, Smokers	$FEV_{1.0}$/FVC, Nonsmokers
CONSTANT	35.54404	-596.47103	-0.00791	0.58291
OZONE	21.15038 (101.49903)	-43.66274 (83.34288)	0.17436 (0.19724)	-0.33708** (0.15155)
CO	858.46059 (703.66308)	-675.54668 (585.18125)	1.61645 (1.38860)	-0.75733 (1.06001)
NO2	-139.71547 (177.44272)	233.20581 (140.25433)	-0.38937 (0.35109)	0.49401* (0.25440)
NO	-477.10936 (422.59835)	-630.01413 (439.15076)	0.72760 (0.81840)	-1.61697** (0.79784)
HUMID	1.95632** (0.69204)	0.98538 (0.62679)	0.00475** (0.00137)	0.00212* (0.00113)
TEMP	2.05934** (0.75571)	0.47845 (0.57293)	0.00609** (0.00150)	0.00215** (0.00103)
AGE	-5.08527** (0.68980)	-3.58388** (0.44972)	---	---
HEIGHT	3.40367 (1.99334)	15.31423** (1.43680)	---	---
R^2	0.301	0.406	0.142	0.041
F	11.178	25.945	5.794	2.188
N	217	312	217	312

*Significant at α = 0.10
**Significant at α = 0.05

variable does not require the inclusion of control variables for individuals since the transformation accomplishes that objective.

For the regressions using MAXFEV as the dependent variable, none of the air pollution variables have coefficients statistically different from zero. The only coefficients statistically significant involve HUMID, TEMP, AGE, or HEIGHT.

For the regressions using $FEV_{1.0}/FVC$ of smokers as the dependent variable, only HUMID and TEMP contribute significantly to the reduction in overall variance. However, the results using $FEV_{1.0}/FVC$ of nonsmokers indicate that OZONE, NO_2, NO, HUMID, and TEMP are statistically significant. But in the latter use, the overall measure of the goodness of fit, $R^2 = 0.04$, is small indicating that the association is not strong.

These four regression specifications were reestimated after Sub-Panel 3 was excluded from the data. This was done since previous analysis indicated that Sub-Panel 3 was potentially different from the others. The results reported in Table 65 do not indicate any stronger associations than before. In the MAXFEV regressions, only HUMID, AGE, and HEIGHT are statistically significant. In the $FEV_{1.0}/FVC$ regressions, only HUMID and TEMP are significant for smokers while none of the explanatory variables are significant for nonsmokers.

Alternative linear specifications were estimated which utilized a dummy variable for sub-panels tested on different dates. As with the asthma panel, there were four sub-panels in the outdoor worker panel. Sub-Panel (Group) 1 was used as the base group; G2 = 1 if the observation was for Sub-Panel (Group) 2; G3 = 1 if the observation was for Sub-Panel (Group) 3; G4 = 1 if the observation was for Sub-Panel (Group) 4. The results are reported in Table 66.

Apart from the dummy variables, the only statistically significant variables explaining MAXFEV from smokers or nonsmokers are TEMP, AGE, or HEIGHT. Also, for the regressions predicting $FEV_{1.0}/FVC$ for smokers, none of the air pollution variables are statistically significant. However, for the $FEV_{1.0}/FVC$ regression for nonsmokers, CO is statistically significant. None of the other explanatory variables are significant, and the implied inverse correlation between $FEV_{1.0}/FVC$ and CO may be spurious.

Lagged Explanatory Variables

The average level of each of the air pollution variables was computed for each date. These variables were then lagged one day and used as explanatory variables with MAXFEV as the

TABLE 65. MULTIVARIATE REGRESSIONS FOR MAXFEV AND $FEV_{1.0}/FVC$--SMOKERS
AND NONSMOKERS WITH SUB-PANEL 3 EXCLUDED
(STANDARD ERRORS IN PARENTHESES)

Variable	MAXFEV, Smokers	MAXFEV, Nonsmokers	$FEV_{1.0}/FVC$, Smokers	$FEV_{1.0}/FVC$, Nonsmokers
CONSTANT	210.72203	-268.38956	0.11536	0.85057
OZONE	110.85588 (117.66221)	58.43143 (123.20335)	0.34284 (0.23431)	-0.08167 (0.20626)
CO	326.03352 (784.31580)	-813.61658 (799.60494)	0.51066 (1.58060)	-2.03921 (1.33654)
NO2	-240.98382 (201.59030)	50.50919 (180.47025)	-0.61154 (0.91546)	0.36832 (0.95562)
NO	-202.14476 (466.18577)	-88.68855 (571.31320)	1.55049 (0.91546)	-0.52144 (0.95562)
HUMID	1.72680** (0.74427)	0.54677 (0.81066)	0.00394** (0.00151)	0.00044 (0.00315)
TEMP	1.31751 (0.94992)	0.04526 (0.85769)	0.00531** (0.00192)	-0.00014 (0.00143)
AGE	-5.78183** (0.75212)	-4.41017** (0.85769)	---	---
HEIGHT	2.34305 (2.11581)	11.89836** (0.56207)	---	---
R^2	0.351	0.426	0.149	0.028
F	11.814	18.109	5.175	0.955
N	184	204	184	204

**Significant at $\alpha = 0.05$

TABLE 66. MULTIVARIATE REGRESSIONS FOR MAXFEV AND $FEV_{1.0}$/FVC--SMOKERS
AND NONSMOKERS WITH DUMMY VARIABLE INCLUDED FOR SUB-PANELS
(STANDARD ERRORS IN PARENTHESES)

Variable	MAXFEV, Smokers	MAXFEV, Nonsmokers	$FEV_{1.0}$/FVC, Smokers	$FEV_{1.0}$/FVC, Nonsmokers
CONSTANT	479.22652	-424.99038	0.92505	0.76546
OZONE	-25.22124 (91.82008)	-1.89032 (92.17671)	-0.09735 (0.18476)	-0.00526 (0.16546)
CO	-29.93116 (654.48034)	-975.73363 (641.04083)	0.70104 (1.31966)	-2.32312** (1.14889)
NO2	-18.29724 (150.55112)	182.93001 (127.81478)	0.04675 (0.30356)	0.39861 (0.22901)
HUMID	-0.95098 (0.69681)	0.01643 (0.72906)	-0.00062 (0.00141)	0.00075 (0.00131)
TEMP	-1.60883** (0.81854)	-0.38070 (0.73550)	-0.00093 (0.00165)	0.00053 (0.00132)
AGE	-5.32284** (0.60779)	-3.63778** (0.44951)	---	---
HEIGHT	4.19671** (1.70719)	14.64094** (1.45461)	---	---
G2	-21.66984 (11.74915)	3.40644 (12.61516)	-0.04844** (0.02352)	0.01572 (0.02264)
G3	19.93225 (13.31532)	9.46227 (11.00845)	0.00277 (0.02639)	0.06848 (0.01972)
G4	-113.58543** (17.14194)	-17.96280 (15.93409)	-0.23143 (0.03453)	0.01777 (0.02847)
R^2	0.476	0.413	0.331	0.076
F	18.716	21.139	12.866	3.111
N	217	312	217	312

**Significant at $\alpha = 0.05$

dependent variable. The results are reported in Table 67. Only AGE, HEIGHT, and COLD are statistically significant. None of the lagged air pollution variables are statistically signifi-cant. Moreover, the analysis did not suggest that lags of greater magnitude or weighted averages of the lagged values would yield more significant results. The data do not support a hypothesis that lagged or cumulative exposure to air pollution significantly affected MAXFEV.

TABLE 67. MULTIVARIATE REGRESSIONS OF MAXFEV WITH ONE-DAY LAGGED AIR POLLUTION VARIABLES

Variable	β	Standard Error	$F = t^2$
CONSTANT	-311.325	---	---
OZONE-1	-44.596	0.207	0.587
CO-1	-442.751	382.181	1.342
NO2-1	60.849	88.598	0.472
NO-1	157.758	276.817	0.325
HUMID-1	-0.689	0.416	2.744
TEMP-1	-0.548	0.434	1.592
AGE	-4.069	0.313	168.592
HEIGHT	13.903	1.030	182.183
COLD	-15.978	7.538	4.493

$R^2 = 0.394$

$N = 589$

$F = 41.844$

In addition to the average value of each of the air pol-lution variables being lagged one day, the averages were lagged two and three days. The lagged variables were then used as ex-planatory variables along with AGE, HEIGHT, and COLD. The de-pendent variable was MAXFEV. Again, the only variables statisti-

cally significant in these regressions were AGE and HEIGHT. TEMP was statistically significant in the three-day lag specification. But none of the air pollution variables were significant in either the two- or three-day specifications.

Summary of the Multivariate Analysis

Alternative linear regression specifications estimated for data obtained from the outdoor worker panel used MAXFEV and $FEV_{1.0}/FVC$ as dependent variables. Separate regressions were used to control for differences between individuals and sub-panels. The Hasselblad model included a dummy variable for each individual tested. The more standard linear specification either included AGE and HEIGHT variables or applied the $FEV_{1.0}/FVC$ transformation to control for differences between individuals. A dummy variable technique was also applied to each of the four sub-panels. Finally, the air pollution variables were averaged and lagged to investigate the possibility of lagged effects of air pollution on the pulmonary function results.

The conclusion is that differences in MAXFEV are explained quite well by AGE and HEIGHT and other explanatory variables which controlled for differences between individuals. But MAXFEV measured for the outdoor worker panel was not statistically sensitive to air pollution variables in the multivariate specifications.

OVERALL SUMMARY OF THE OUTDOOR WORKER PANEL DATA ANALYSIS

The levels of air pollution in the study area were light to moderate during the 54 days of outdoor worker testing. Typical seasonal changes were observed in the concentrations of the air pollutants. Maximum hourly averages of ozone gradually declined from around 0.30 ppm to 0.05 ppm, while concentrations of nitrogen dioxide increased from 0.01 ppm to around 0.30 ppm. The average values of these and the other aerometric variables at the times outdoor worker panelists reported their symptoms (i.e., the weighted averages of these variables) are presented in Table 30D. The weighted averages of responses to daily symptom interviewing and to pulmonary function testing are shown in Tables 30A and 30C. The symptom and aerometric data are compared graphically in Appendix J.

The data from the outdoor worker panel provided the most significant results. It is believed that this happened because the panel members were exposed to concentrations of air pollutants while at work out of doors.

The analysis of the data involved several statistical tests. Significant results were obtained from most of them. For example, correlation analyses were performed on the data of the outdoor worker panel. Both parametric and non-parametric correlations were computed and tested for statistical significance. Eye discomfort, chest discomfort, cough, and phlegm were positively correlated with ozone. Eye discomfort was also positively correlated with all of the other aerometric variables.

The correlation analysis was replicated separately for smokers and nonsmokers of the outdoor worker panel. There were more significant correlations for smokers than for the outdoor worker panel as a whole. Headache was not significant for the entire panel but was positively correlated with ozone for smokers. The total number of significant correlations for nonsmokers was smaller than for the entire panel. This was particularly true for the discomfort symptoms--shortness of breath, cough, and phlegm. However, MAXFEV was negatively correlated with ozone and statistically significant only for the non-smokers. The nonsmoking outdoor workers seemed to be more responsive in terms of decreased lung function to the air pollution variables than any other group examined in this study. These differences between smokers and nonsmokers in the outdoor workers panel indicated that separate treatment of the two groups was appropriate.

Single variable linear regressions were estimated with MAXFEV as the dependent variable. Most of the air pollution variables were significantly related to MAXFEV for smokers. However, the sign of the coefficient for ozone was positive. For nonsmokers, only ozone was statistically significant and the sign of the coefficient was negative.

Contingency tables were constructed and chi-square tests of association were made between MAXFEV and the air pollution variables. These tests supported the hypothesis of dependence between MAXFEV and the air pollution variables for the outdoor worker panel.

Linear probability functions were estimated using the dichotomous discomfort variables as dependent and the air pollution variables as explanatory. The relationship of eye discomfort with ozone was stronger for smokers than for nonsmokers. Eye discomfort, throat discomfort, chest discomfort, shortness of breath, and cough were all directly related to ozone.

There were fewer significant linear probability regressions for nonsmokers. However, eye discomfort was significantly related to all the air pollution variables for the nonsmokers.

Multivariate linear probability regressions were estimated for the whole outdoor worker panel. The data were restricted to those outdoor workers who reported not having a cold and not taking medication. The results showed reports of eye discomfort, chest discomfort, shortness of breath, cough, and phlegm to be significantly related to concentrations of the air pollutants.

Discomfort symptoms were analyzed by computing proportions of the symptoms and the means of the air pollution variables for each of the 54 days of surveillance. Single variable and multivariate regressions were performed using both the linear probability and LOGIT probability specifications. The simple linear probability regressions resulted in several statistically significant associations. Eye discomfort, throat discomfort, shortness of breath, and cough were significantly related to ozone. Multivariate regressions resulted in only eye discomfort and shortness of breath having consistently significant estimates after a correction for heteroscedasticity was applied. And, only ozone remained statistically significant as an explanatory variable.

SECTION 9

DATA ANALYSIS--BRONCHITIS PANEL

STATISTICAL DESCRIPTION OF THE BRONCHITIS PANEL

This panel, like the asthma panel, was composed entirely of females. All of the bronchitics selected for participation smoked cigarettes; all were in the 35 to 55 age bracket. The bronchitis panel was tested on 12 days over a period of seven weeks. Although 54 females were selected for participation, only 38 attended testing sessions regularly enough for sufficient test results to be entered into the data file for analysis. Table 68 summarizes the composition of the bronchitis panel.

TABLE 68.   COMPOSITION OF THE
BRONCHITIS PANEL

Characteristics	Total Panel
Subjects enrolled in panel (all female)	38
Current cigarette smokers	38
Subjects 31 to 40 years old	14
Subjects 41 to 50 years old	14
Subjects over 50 years old	10
Subjects with 12 or more years of school completed	28
Race other than white	2

The comprehensive clinical examinations administered before and after the testing period and the clinical interviews held after the testing period confirmed that all but one of the

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panelists had symptoms of bronchitis. Even this single panelist exhibited symptoms of bronchitis during the testing period. The types of data obtained from each bronchitis panelist are listed in Section 4 of this report. All data were included in the analysis except for heart function measures and the results of the hematological and nasal smear evaluations. The latter data were eliminated for the following reasons.

Heart function was evaluated by measuring blood pressure, heart rate, and 12-lead electrocardiograms. The electrocardiograms were converted to a digital format that yielded 44 descriptive codes or numerial quantities. All the measures of heart function stayed essentially constant throughout the testing period for all panelists, so they were not included in the numerical data analysis.

A complete hematological analysis was obtained on venous blood samples which were taken on four or five selected testing days. Immunoglobulins were also determined. The measures of MCV, MCH, and MCHC remained nearly constant for all panelists and therefore were not used in the statistical analysis. The counts of basophiles and monocytes were so low that analysis against air pollution variables was not possible. Differential counts were converted to absolute counts for the statistical analysis. There were few significant correlations of any sort, and there was no indication of any systematic association between air pollution levels and any of the blood components.

Nasal smears were taken from each panelist and submitted for a semiquantitative determination of eosinophiles. The results were categorized as "negative," "few," "moderate," or "many." Most of the readings were "negative," so no attempt was made to analyze the results by any formal method.

Description of the Variables

The discomfort symptom variables were measured with the form shown in Appendix F. The same coding was used on the responses as in the other panels: unity for "Yes," zero for "No." A statistical profile of the discomfort variables is given in Table 69A. The variables were the same as those measured of the asthma panel.

Two pulmonary function variables were used in the analysis of the bronchitis panel. MAXFVC was the best of five maneuvers attained each study day by each panelist. Variable MAXFEV was the highest $FEV_{1.0}$ taken from the volume-time tracings of the FVC maneuvers. The AGE and HEIGHT of each panelist were recorded as age in years and standing height in inches. These data were used to adjust the MAXFVC and MAXFEV scores prior to

TABLE 69A. STATISTICAL PROFILE OF DISCOMFORT SYMPTOMS REPORTED BY BRONCHITIS PANELISTS ON 11 TESTING DAYS

VARIABLE: EYES = Eye discomfort now

MEAN	= 0.478	RANGE	= 1.000
VARIANCE	= 0.250	MINIMUM	= 0.000
KURTOSIS	= -1.989	MAXIMUM	= 1.000
STD DEV	= 0.500	VALID OBS	= 362
SKEWNESS	= 0.089	MISSING OBS	= 0

VARIABLE: THROAT = Throat discomfort now

MEAN	= 0.459	RANGE	= 1.000
VARIANCE	= 0.249	MINIMUM	= 0.000
KURTOSIS	= -1.969	MAXIMUM	= 1.000
STD DEV	= 0.499	VALID OBS	= 362
SKEWNESS	= 0.167	MISSING OBS	= 0

VARIABLE: CHEST = Chest discomfort now

MEAN	= 0.547	RANGE	= 1.000
VARIANCE	= 0.248	MINIMUM	= 0.000
KURTOSIS	= -1.962	MAXIMUM	= 1.000
STD DEV	= 0.498	VALID OBS	= 362
SKEWNESS	= -0.189	MISSING OBS	= 0

VARIABLE: HEADACHE = Headache now

MEAN	= 0.343	RANGE	= 1.000
VARIANCE	= 0.226	MINIMUM	= 0.000
KURTOSIS	= -1.556	MAXIMUM	= 1.000
STD DEV	= 0.475	VALID OBS	= 362
SKEWNESS	= 0.665	MISSING OBS	= 0

VARIABLE: NAUSEA = Nausea now

MEAN	= 0.091	RANGE	= 1.000
VARIANCE	= 0.083	MINIMUM	= 0.000
KURTOSIS	= 6.095	MAXIMUM	= 1.000
STD DEV	= 0.288	VALID OBS	= 362
SKEWNESS	= 2.849	MISSING OBS	= 0

VARIABLE: OTHER = Other discomfort now

MEAN	= 0.149	RANGE	= 1.000
VARIANCE	= 0.127	MINIMUM	= 0.000
KURTOSIS	= 1.893	MAXIMUM	= 1.000
STD DEV	= 0.357	VALID OBS	= 362
SKEWNESS	= 1.975	MISSING OBS	= 0

VARIABLE: HEADACHE EARLIER = Headache earlier today

MEAN	= 0.348	RANGE	= 1.000
VARIANCE	= 0.228	MINIMUM	= 0.000
KURTOSIS	= -1.589	MAXIMUM	= 1.000
STD DEV	= 0.477	VALID OBS	= 362
SKEWNESS	= 0.640	MISSING OBS	= 0

VARIABLE: BREATH = Shortness of breath today

MEAN	= 0.392	RANGE	= 1.000
VARIANCE	= 0.239	MINIMUM	= 0.000
KURTOSIS	= -1.802	MAXIMUM	= 1.000
STD DEV	= 0.489	VALID OBS	= 362
SKEWNESS	= 0.443	MISSING OBS	= 0

VARIABLE: COUGH = Cough today

MEAN	= 0.856	RANGE	= 1.000
VARIANCE	= 0.123	MINIMUM	= 0.000
KURTOSIS	= 2.143	MAXIMUM	= 1.000
STD DEV	= 0.351	VALID OBS	= 362
SKEWNESS	= -2.038	MISSING OBS	= 0

VARIABLE: PHLEGM = Phlegm today

MEAN	= 0.884	RANGE	= 1.000
VARIANCE	= 0.103	MINIMUM	= 0.000
KURTOSIS	= 3.792	MAXIMUM	= 1.000
STD DEV	= 0.320	VALID OBS	= 311
SKEWNESS	= -2.410	MISSING OBS	= 0

VARIABLE: COLD = Bad cold today

MEAN	= 0.075	RANGE	= 1.000
VARIANCE	= 0.069	MINIMUM	= 0.000
KURTOSIS	= 8.520	MAXIMUM	= 1.000
STD DEV	= 0.263	VALID OBS	= 362
SKEWNESS	= 3.247	MISSING OBS	= 0

VARIABLE: MEDICINE = Medicine today

MEAN	= 0.328	RANGE	= 1.000
VARIANCE	= 0.221	MINIMUM	= 0.000
KURTOSIS	= -1.457	MAXIMUM	= 1.000
STD DEV	= 0.470	VALID OBS	= 360
SKEWNESS	= 0.736	MISSING OBS	= 2

analysis: A profile of the pulmonary function variables is given in Table 69B. MAXFVC and MAXFEV are shown in hundred liters (liters x 100).

The air pollution and weather variables used in this analysis are the same as those used in the asthma panel analysis. A profile of these variables is given in Table 69C. The air pollution variables were obtained as hourly averages measured in ppm (CO im ppm/100). Relative humidity was estimated by hour and expressed in percent. A discussion on how the estimates were made is given in the paragraphs of Section 7 which describe the variables used in the asthma panel analysis. Temperature was obtained as hourly averages measured in degrees Fahrenehit.

There were no missing observations for any of the discomfort symptom variables, except for phlegm. The highest number of missing observations were those for MAXFVC and $FEV_{1.0}$, with 110 or 30 percent missing. Still, a sufficient number were available for use in data analysis. Among the air pollution variables, NO_2 and NO had a sizeable number of missing observations, but there were enough data points to include both of these pollutants in the analysis.

Weighted averages of exposure to air pollutant, humidity, and temperature levels were used in the analysis of the bronchitis panel. As in the analysis of the asthma panel, the hour at which each panelist reported for testing was noted and the aerometric values for that hour were included in the weighted average for that day.

The proportions of bronchitis panelists who reported discomfort symptoms are shown in Appendix K for each of the 12 days when symptom data were collected. The weighted averages of the air pollutants, relative humidity, and temperature are also given in Appendix K for each of the same days. The charts are provided to facilitate comparisons between proportions of panelists who reported symptoms and the weighted averages of air pollution.

CORRELATION ANALYSIS

Pearson and non-parametric correlation analyses were applied to the data collected from the bronchitis panel. The results are presented below.

Pearson Correlation

The Pearson correlation coefficients for the bronchitis panel are reported in Table 70. The significant levels are indicated at $\alpha = 0.01$, $\alpha = 0.05$, and $\alpha = 0.10$. The pulmonary

TABLE 69B. STATISTICAL PROFILE OF PULMONARY FUNCTION
VARIABLES AND AGE AND HEIGHT OF BRONCHITIS
PANELISTS MEASURED ON 12 TESTING DAYS

VARIABLE: MAXFVC = Maximum FVC (in liters x 100)

MEAN	= 266.623	RANGE	= 323.000
VARIANCE	= 5,648.419	MINIMUM	= 94.000
KURTOSIS	= -0.614	MAXIMUM	= 417.000
STD DEV	= 75.156	VALID OBS	= 252
SKEWNESS	= -0.218	MISSING OBS	= 110

VARIABLE: MAXFEV = Maximum $FEV_{1.0}$ (in liters x 100)

MEAN	= 212.266	RANGE	= 290.000
VARIANCE	= 4,619.893	MINIMUM	= 54.000
KURTOSIS	= -0.238	MAXIMUM	= 344.000
STD DEV	= 67.970	VALID OBS	= 252
SKEWNESS	= -0.280	MISSING OBS	= 110

VARIABLE: AGE = Age of panelist (in years)

MEAN	= 44.622	RANGE	= 20
VARIANCE	= 44.377	MINIMUM	= 35
KURTOSIS	= -1.478	MAXIMUM	= 55
STD DEV	= 6.662	VALID OBS	= 43
SKEWNESS	= -0.050	MISSING OBS	= 2

VARIABLE: HEIGHT = Height of panelist (in inches)

MEAN	= 63.156	RANGE	= 13
VARIANCE	= 7.680	MINIMUM	= 56
KURTOSIS	= 0.270	MAXIMUM	= 69
STD DEV	= 2.771	VALID OBS	= 43
SKEWNESS	= 0.375	MISSING OBS	= 2

TABLE 69C. STATISTICAL PROFILE OF AIR POLLUTION
VARIABLES MEASURED ON 11 BRONCHITIS PANEL TESTING DAYS

VARIABLE: OZONE = Estimate for oxidant (in ppm)

MEAN	=	0.082	RANGE	=	0.260
VARIANCE	=	0.004	MINIMUM	=	0.010
KURTOSIS	=	0.714	MAXIMUM	=	0.270
STD DEV	=	0.067	VALID OBS	=	360
SKEWNESS	=	1.154	MISSING OBS	=	2

VARIABLE: CO = Carbon monoxide (in ppm/100)

MEAN	=	0.036	RANGE	=	0.060
VARIANCE	=	0.000	MINIMUM	=	0.020
KURTOSIS	=	0.344	MAXIMUM	=	0.080
STD DEV	=	0.013	VALID OBS	=	361
SKEWNESS	=	0.686	MISSING OBS	=	1

VARIABLE: NO2 = Nitrogen dioxide (in ppm)

MEAN	=	0.081	RANGE	=	0.250
VARIANCE	=	0.002	MINIMUM	=	0.020
KURTOSIS	=	5.795	MAXIMUM	=	0.270
STD DEV	=	0.045	VALID OBS	=	333
SKEWNESS	=	2.069	MISSING OBS	=	29

VARIABLE: NO = Nitric oxide (in ppm)

MEAN	=	0.015	RANGE	=	0.050
VARIANCE	=	0.000	MINIMUM	=	0.010
KURTOSIS	=	8.400	MAXIMUM	=	0.060
STD DEV	=	0.009	VALID OBS	=	328
SKEWNESS	=	2.665	MISSING OBS	=	34

VARIABLE: HUMID = Relative humidity (in percent)

MEAN	=	59.712	RANGE	=	25.000
VARIANCE	=	78.256	MINIMUM	=	50.000
KURTOSIS	=	-0.901	MAXIMUM	=	75.000
STD DEV	=	8.846	VALID OBS	=	361
SKEWNESS	=	0.399	MISSING OBS	=	1

VARIABLE: TEMP = Temperature (in degrees Fahrenheit)

MEAN	=	77.393	RANGE	=	37.000
VARIANCE	=	95.823	MINIMUM	=	58.000
KURTOSIS	=	-1.001	MAXIMUM	=	95.000
STD DEV	=	9.789	VALID OBS	=	361
SKEWNESS	=	0.134	MISSING OBS	=	1

TABLE 70. PEARSON CORRELATION COEFFICIENTS FOR THE BRONCHITIS PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.15***	0.08	0.09	0.03	-0.07	0.05
THROAT	0.01	-0.03	-0.00	0.08	0.07	-0.03
CHEST	-0.04	0.05	0.12**	0.14**	0.08	-0.07
HEADACHE	-0.13**	-0.02	0.04	0.04	0.10**	-0.16***
NAUSEA	0.04	0.06	0.04	-0.04	0.05	-0.05
OTHER	0.00	0.01	0.02	0.01	-0.08	0.07
HEADACHE EARLIER	-0.15***	0.03	0.09	0.11**	0.10*	-0.13**
BREATH	-0.04	0.08	0.03***	0.22***	-0.07	0.03
COUGH	-0.02	0.02	0.02	0.13**	-0.03	-0.01
PHLEGM	-0.10**	0.02	-0.00	0.01	0.05	-0.08
MAXFVC	-0.01	0.03	0.04	-0.04	-0.04	0.00
MAXFEV	-0.00	0.07	0.07	0.02	-0.03	-0.03

*Significant at α = 0.10
**Significant at α = 0.05
***Significant at α = 0.01

function variables, MAXFVC and MAXFEV, are not significantly correlated with any of the air pollution variables for the bronchitis panel.

Examination of the correlations between the qualitative discomfort variables and the air pollution variables reveals several significant correlations. Variables EYES is positively correlated with OZONE, at $\alpha = 0.01$, but EYES does not have significant Pearson correlation coefficients with respect to any of the other air pollution variables. CHEST has significant positive correlations with NO_2 and NO. HEADACHE variable is negatively correlated with OZONE at a level of significance of $\alpha = 0.05$, and HEADACHE is also significantly correlated with HUMID and TEMP. BREATH, the variable indicating shortness of breath, is positively correlated with NO_2 and NO at $\alpha = 0.01$, COUGH is only significantly correlated with NO. Finally, PHLEGM is negatively correlated with OZONE at $\alpha = 0.05$. None of the other correlations were significant at a level better than $\alpha = 0.10$. These results need to be compared to the more appropriate non-parametric correlations.

Non-Parametric Correlations

The Spearman and Kendall correlation coefficients are reported in Tables 71 and 72, respectively. The computed Spearman and Kendall correlations reinforce each other, but they are different in some respects to the Pearson correlations. EYES is now significantly correlated with OZONE, CO, and NO_2 at $\alpha = 0.10$ or better. Variables THROAT and CHEST are now significantly correlated with HUMID; however, the level of significance is not strong. CHEST is correlated with NO_2 and NO at a greater level of significance, $\alpha = 0.01$, than is estimated by the Pearson correlations.

Variable NAUSEA is again not significantly correlated with any of the air pollution variables. However, OTHER is now significantly correlated with HUMID and TEMP. BREATH is now significantly correlated with HUMID as well as with NO_2 and NO. COUGH remains significantly correlated with NO, but it is significantly correlated with TEMP at $\alpha = 0.05$.

Based on the results of the correlation analysis, further analysis of EYES, CHEST, HEADACHE, BREATH, and COUGH seemed warranted and was undertaken as described below. But due to the lack of statistically significant relationships of THROAT, NAUSEA, OTHER and PHLEGM with the air pollution variables, these discomfort symptom variables were not included in further analysis of the bronchitis panel. For this panel, the results for HEADACHE and HEADACHE EARLIER were almost identical. This cast doubt on the usefulness of HEADACHE EARLIER as a different measure of the effects of air pollution; thus, HEADACHE EARLIER was also dropped from further analysis.

TABLE 71. SPEARMAN CORRELATION COEFFICIENTS FOR THE BRONCHITIS PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.08*	0.09**	0.09*	0.04	-0.07	0.06
THROAT	-0.02	-0.03	0.04	0.06	0.07*	-0.02
CHEST	-0.06	0.04	0.13***	0.14***	0.07*	-0.06
HEADACHE	-0.13***	-0.02	0.03	0.05	0.10**	-0.16***
NAUSEA	0.02	0.06	0.03	-0.00	0.04	-0.05
OTHER	0.00	-0.00	-0.00	0.05	-0.09**	0.07*
HEADACHE EARLIER	-0.17***	0.04	0.11**	0.12**	0.09**	-0.13***
BREATH	-0.03	0.07	0.19***	0.27***	-0.08*	0.03
COUGH	-0.01	0.02	0.03	0.12**	-0.03	-0.01
PHLEGM	-0.05	0.02	-0.01	-0.14	0.05	-0.08***

*Significant at $\alpha = 0.10$
**Significant at $\alpha = 0.05$
***Significant at $\alpha = 0.01$

TABLE 72. KENDALL CORRELATION COEFFICIENTS FOR THE BRONCHITIS PANEL

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES	0.07*	0.08**	0.08*	0.04	-0.06	0.05
THROAT	-0.02	-0.02	0.03	0.06	0.07*	-0.01
CHEST	-0.05	0.04	0.11***	0.14***	0.07*	-0.05
HEADACHE	-0.11***	-0.02	0.02	0.05	0.09**	-0.13***
NAUSEA	0.02	0.06	0.02	-0.00	0.03	-0.04
OTHER	0.00	-0.00	-0.00	0.05	-0.09**	0.06*
HEADACHE EARLIER	-0.14***	0.03	0.09**	0.12**	0.09**	-0.11***
BREATH	-0.03	0.06	0.16***	0.26***	-0.08*	0.03
COUGH	-0.01	0.01	0.03	0.12**	-0.03	-0.01
PHLEGM	-0.04	0.02	-0.01	-0.03	0.05	-0.07*

*Significant at α = 0.10
**Significant at α = 0.05
***Significant at α = 0.01

MEASURES OF ASSOCIATION BETWEEN VARIABLES

In parallel with the analyses of the asthma and outdoor worker panels, attempts were made to identify and evaluate associations between variables in the bronchitis panel. Several methods were applied. The results are explained on the following pages.

Simple Linear Regressions of FVC and $FEV_{1.0}$

Simple linear regressions were computed with MAXFVC or MAXFEV as the dependent variable. None produced statistically significant results. Inspection of scattergrams revealed no non-linear relationship for MAXFVC or MAXFEV with the air pollution variables for unrestricted bronchitis data.

Contingency Tables Between $FEV_{1.0}$ and the Air Pollution Variables

Contingency tables were constructed using MAXFEV as the row variable and the air pollution variables as the column variables. MAXFEV was divided into the same classes as the asthma panel. The classes for the air pollution variables were also the same as for the asthma panel (refer to Section 7). All of the tables are (2x2) and have critical values of the $\chi^2 = 6.63$ at $\alpha = 0.01$, $\chi^2 = 3.84$ at $\alpha = 0.05$, and $\chi^2 = 2.70$ at $\alpha = 0.10$. Computed χ^2 values greater than the chosen critical value lead to rejection of the hypothesis of independence between the variable classes.

None of the computed χ^2 values are significant at $\alpha = 0.10$. Thus, the hypothesis of independence between MAXFEV and the air pollution variables OZONE, CO, NO^2, and NO is not rejected. The bronchitis panel showed no strong sensitivity to the levels of air pollution measured during the tests.

Linear Probability Model

Linear probability functions were estimated for the bronchitis panel for each of the discomfort symptom variables. The explanatory variable for each was a different measure of air pollution. The regressions which were significant at $\alpha = 0.05$, or better, are reported in Table 73. At first glance, the coefficients of determination may seem small, but given a binary dependent variable, it is impossible to obtain $R^2 = 1$ when fitting a straight line to the data.

TABLE 73. SIMPLE LINEAR PROBABILITY REGRESSIONS FOR THE BRONCHITIS PANEL

Prob(EYES)	= 0.086 + 1.114(OZONE)***	R^2 = 0.022
Prob(CHEST)	= 0.455 + 1.273(NO2)***	R^2 = 0.013
Prob(CHEST)	= 0.446 + 7.718(NO)**	R^2 = 0.019
Prob(HEADACHE)	= 0.421 - 0.927(OZONE)**	R^2 = 0.017
Prob(HEADACHE)	= 0.011 + 0.006(HUMID)**	R^2 = 0.011
Prob(HEADACHE)	= 0.933 - 0.008(TEMP)***	R^2 = 0.025
Prob(BREATH)	= 0.205 + 2.500(NO2)***	R^2 = 0.053
Prob(BREATH)	= 0.233 + 12.106(NO)***	R^2 = 0.050
Prob(COUGH)	= 0.787 + 4.942(NO)***	R^2 = 0.016

**Significant at α = 0.05

***Significant at α = 0.01

EYES is significantly related to OZONE. Given an increase in OZONE of 0.10 will increase the probability of experiencing eye discomfort by approximately 0.10 or 10 percent. CHEST is significantly related to NO_2 and NO. The proportion of bronchitics experiencing chest discomfort will increase by approximately 0.13 or 13 percent given an increase in NO_2 of 0.10. That proportion is predicted to increase about 0.08 or 8 percent for a 0.01 increase in NO.

HEADACHE is significantly related to OZONE, HUMID, and TEMP. However, the level of significance is not strong for OZONE and HUMID. And the sign of the coefficient attached to OZONE is suspect. BREATH is significantly related to NO_2 and NO. The percentage of respondents experiencing shortness of breath is predicted to increase by 0.25 or 25 percent given a 0.10 increase in NO_2. That percentage will increase by 0.12 or 12 percent given a 0.01 increase in NO. Finally, COUGH is significantly related to NO. A 0.05 or 5 percent increase in the percentage of bronchitics having a cough is predicted for each 0.01 increase in NO.

SELECTED MULTIVARIATE LINEAR PROBABILITY REGRESSIONS

The previous section showed five discomfort symptom variables which demonstrated significant statistical association with some of the air pollution variables. Those discomfort symptom variables are EYES, CHEST, HEADACHE, BREATH, and COUGH. Multivariate linear probability specifications were estimated for each using the qualitative discomfort symptom as the dependent variables with OZONE, CO, NO_2, HUMID, TEMP, and COLD as explanatory variables. The potential explanatory variable NO was excluded because it was expected to be collinear with NO_2. The results are reported in Table 74 except for the regression with COUGH as the dependent variable. That regression has no statistically significant coefficients for any of the explanatory variables.

For EYES as the dependent variable, only NO_2 has a statistically significant coefficient. This result may be contrasted to the single linear probability regression where OZONE has the only coefficient that was statistically significant. It appears that when HUMID, TEMP, and COLD are included as control variables in the multivariate specification, NO_2 explains more of the variation in eye discomfort than OZONE. The simple linear probability regressions for CHEST show NO_2 and NO as significant explanatory variables. Likewise, the multivariate regressions show NO_2 as a significant explanatory variable, but NO is not included. The simple regressions for HEADACHE show OZONE, HUMID, and TEMP are no longer significant in the presence of the other variables. CO and NO_2 are statistically significant explanatory variables; however, the sign of the CO coefficient is negative. The multivariate specification for BREATH resulted in CO and NO_2 having statistically significant coefficients, but again the CO coefficient is negative.

DISCOMFORT SYMPTOMS ANALYZED BY DATE OF MEASUREMENT

The bronchitis panel was tested on 11 different dates. On each date, the proportion of the panelists reporting each discomfort symptom was computed. On each date, the average level of each air pollution variable was also computed. The average levels of air pollution were then related to the proportion of panelists reporting each discomfort symptom on each date. This was done using two regression techniques.

Simple Linear Regressions

The LOGIT specification was applied to selected discomfort symptom proportions. The discomfort variables chosen were EYES, CHEST, HEADACHE, BREATH, and COUGH. The explanatory variables were OZONE, CO, NO_2 and NO. The linear probability specification was also estimated. The form of these specifications is

TABLE 74. MULTIVARIATE LINEAR PROBABILITY REGRESSIONS FOR
THE BRONCHITIS PANEL
(STANDARD ERRORS IN PARENTHESES)

Explanatory Variable	Dependent Variable			
	EYES	CHEST	HEADACHE	BREATH
CONSTANT	0.82523	0.39688	2.02789	0.89568
OZONE	1.84982 (0.10597)	0.31416 (0.57754)	0.02662 (0.54309)	0.54533 (0.55941)
CO	-6.30112 (4.33739)	-3.50222 (4.22136)	-9.03733*** (3.96958)	-8.41667*** (4.08887)
NO2	2.16677*** (1.09490)	2.11782*** (1.05382)	1.91167** (0.99096)	4.11930*** (1.02014)
HUMID	-0.00197 (0.00528)	0.00461 (0.00508)	-0.00571 (0.00478)	-0.00398 (0.00492)
TEMP	-0.00452 (0.00550)	-0.00246 (0.00541)	-0.01507 (0.00509)	-0.00417 (0.00524)
COLD	-0.15350 (0.10597)	0.05614 (0.10606)	0.07346 (0.09973)	0.00938 (0.10273)
R^2	0.045	0.027	0.058	0.066
F	2.163	1.492	3.353	3.848
N	332	332	332	332

*Significant at $\alpha = 0.10$

**Significant at $\alpha = 0.05$

discussed in connection with the asthma panel (Section 7) and outdoor worker panel (Section 8). The significant regressions are reported in Table 75. None of the regressions for HEADACHE and COUGH are significant at $\alpha = 0.10$ or better, so they are not reported.

EYES is significantly related to OZONE in both the LOGIT and linear probability regressions. None of the other air pollution variables showed significance in explaining eye discomfort. CHEST is significantly related to NO_2 in both the linear probability and LOGIT regressions. An increase in NO_2 is predicted to cause an increase in the probability of chest discomfort. BREATH has significant predictors, NO_2 and NO, for both the linear probability and LOGIT regressions. An increase in NO_2 and NO is predicted to cause an increase in the proportion of bronchitics experiencing shortness of breath.

Selected Multivariate Regressions

The statistically significant single variable regressions using the proportions of panelists reporting discomfort symptoms involved the EYES, CHEST, and BREATH variables. Therefore, these three variables were used to estimate multivariate probability regression. Linear and LOGIT specifications were estimated with explanatory variables average ozone (AVEOZ), average carbon monoxide (AVECO), average nitrogen dioxide (AVENO2), average temperature (AVETEMP), and average humidity (AVEHUM). Average nitric oxide was excluded to avoid collinearity with AVENO2. The results of the estimations for the linear specification are reported in Table 76, and the results for the LOGIT specification are reported in Table 77.

The total F rejects a hypothesis that all estimated coefficients are simultaneously zero at $\alpha = 0.05$ for all regressions. The R^2 values are all high, indicating that a large percentage of the variation in the respective dependent variables is explained. Explanatory variables AVEOZ, AVECO, and AVENO2 have estimated coefficients significantly different from zero at $\alpha = 0.10$. AVETEMP is statistically significant only once and AVEHUM is not statistically significant at all, but they are retained to avoid biasing the other estimated coefficients.

One phenomenon which should be noted is how the estimated coefficients change in size and significance when compared to the single explanatory variable estimates. OZONE was a significant explanatory variable when used alone only in explaining eye discomfort, but AVEOZ is significant in explaining eye discomfort, chest discomfort, and shortness of breath in the multivariate regressions. Even more striking, CO was not significant in any of the single variable estimates, but AVECO, like AVEOZ, is significant in all of the multivariate estimates. Furthermore, AVENO2 remains significant in explaining chest discomfort

TABLE 75. SIGNIFICANT SIMPLE AND LOGIT REGRESSIONS OF
DISCOMFORT SYMPTOM PROPORTIONS

$$\text{Prob(EYES)} = 0.30564 + 2.09268(\text{OZONE})^{***} \quad R^2 = 0.552$$

$$\ln\left\{\frac{\text{Prob(EYES)}}{1 - \text{Prob(EYES)}}\right\} = -0.82137 + 8.84078(\text{OZONE})^{***} \quad R^2 = 0.556$$

$$\text{Prob(CHEST)} = 0.43526 + 1.29806(\text{NO2})^{***} \quad R^2 = 0.287$$

$$\ln\left\{\frac{\text{Prob(CHEST)}}{1 - \text{Prob(CHEST)}}\right\} = -0.27245 + 5.44977(\text{NO2})^{**} \quad R^2 = 0.291$$

$$\text{Prob(BREATH)} = 0.20190 + 2.50020(\text{NO2})^{**} \quad R^2 = 0.412$$

$$\ln\left\{\frac{\text{Prob(BREATH)}}{1 - \text{Prob(BREATH)}}\right\} = -1.30189 + 10.89243(\text{NO2})^{**} \quad R^2 = 0.416$$

$$\text{Prob(BREATH)} = 0.17715 + 15.17725(\text{NO})^{*} \quad R^2 = 0.258$$

$$\ln\left\{\frac{\text{Prob(BREATH)}}{1 - \text{Prob(BREATH)}}\right\} = -1.40990 + 66.13254(\text{NO})^{*} \quad R^2 = 0.261$$

*Significant at $\alpha = 0.10$

**Significant at $\alpha = 0.05$

***Significant at $\alpha = 0.01$

TABLE 76. MULTIVARIATE LINEAR PROBABILITY REGRESSIONS WITH PROPORTIONS
OF EYE DISCOMFORT, CHEST DISCOMFORT, AND SHORTNESS OF BREATH
AS DEPENDENT VARIABLES
(STANDARD ERRORS IN PARENTHESES)

Prob(EYES)   =   1.432 + 3.630(AVEOZ)**   - 16.519(AVECO)** + 3.821(AVENO2)**
                          (0.605)   (4.721)   (0.844)

                   - 0.10(AVETEMP)** - 0.003(AVEHUM)
                     (0.005)   (0.005)

      R^2 = 0.90, F = 11.01, D.W. = 2.57, N = 12

Prob(CHEST)   =   1.188 + 1.902(AVEOZ)**   - 15.221(AVECO)** + 3.922(AVENO2)**
                          (0.596)   (4.651)   (0.831)

                   - 0.009(AVETEM)   + 0.002(AVEHUM)
                     (0.005)   (0.005)

      R^2 = 0.84, F = 6.34, D.W. = 1.80, N = 12

Prob(BREATH) =   1.987 + 2.704(AVEOZ)**   - 19.267(AVECO)** + 5.328(AVENO2)**
                          (1.234)   (9.622)   (1.720)

                   - 0.012(AVETEMP)   - 0.011(AVEHUM)
                     (0.011)   (0.010)

      R^2 = 0.86, F = 3.36, D.W. = 2.19, N = 12

**Significant at α = 0.05

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TABLE 77. MULTIVARIATE LOGIT PROBABILITY REGRESSIONS WITH PROPORTIONS OF EYE DISCOMFORT, CHEST DISCOMFORT, AND SHORTNESS OF BREATH AS DEPENDENT VARIABLES (STANDARD ERRORS IN PARENTHESES)

$$\ln \left\{ \frac{Prob(EYES)}{1 - Prob(EYES)} \right\} = 4.022 + 15.340(AVEOZ)** - 69.391(AVECO)** + 15.905(AVENO2)**$$

$$\phantom{\ln \left\{ \frac{Prob(EYES)}{1}\right\}} (2.607) \qquad (20.327) \qquad (3.634)$$

$$- 0.043(AVETEMP) \quad - 0.014(AVEHUM)$$

$$(0.023) \qquad (0.021)$$

$$R^2 = 0.90, \; F = 10.47, \; D.W. = 2.58, \; N = 12$$

$$\ln \left\{ \frac{Prob(CHEST)}{1 - Prob(CHEST)} \right\} = 3.024 + 7.952(AVEOZ)** - 64.259(AVECO)** + 16.498(AVENO2)**$$

$$ (2.464) \qquad (19.216) \qquad (3.436)$$

$$- 0.038(AVETEMP) \quad + 0.008(AVEHUM)$$

$$(0.021) \qquad (0.020)$$

$$R^2 = 0.84, \; F = 6.49, \; D.W. = 1.81, \; N = 12$$

$$\ln \left\{ \frac{Prob(BREATH)}{1 - Prob(BREATH)} \right\} = 5.330 + 11.372(AVEOZ)** - 80.713(AVECO) \quad + 22.987(NO2)**$$

$$ (5.358) \qquad (41.784) \qquad (7.471)$$

$$- 0.042(AVETEMP) \quad - 0.040(AVEHUM)$$

$$(0.046) \qquad (0.043)$$

$$R^2 = 0.86, \; F = 3.33, \; D.W. = 2.15, \; N = 12$$

**Significant at $\alpha = 0.05$

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and shortness of breath, but it is not significant in explaining eye discomfort in the multivariate regression. The sign of the coefficients remains consistent, but the coefficients change in magnitude indicating that the variables probably interact in their effect on the discomfort symptoms.

OVERALL SUMMARY OF THE BRONCHITIS PANEL DATA ANALYSIS

Air pollution levels were light to moderate on the 12 days members of the bronchitis panel were tested. The weighted values of the air pollution and weather variables are presented in Table 69C. The weighted averages of responses to symptom interviewing and pulmonary function testing are shown in Tables 69A and 69B. The symptom and aerometric data are compared graphically in Appendix K.

Correlation analysis did not demonstrate any statistically significant association between MAXFVC or MAXFEV and the air pollution variables for the bronchitis panel. Scattergrams and contingency tables upheld this finding. The results were not so sparse for the discomfort symptoms, however,

Parametric and non-parametric correlation coefficients were statistically significant for eye discomfort with OZONE, CO, and NO_2. Chest discomfort and shortness of breath were significantly correlated with NO_2 and NO. Finally, having a cough was correlated with NO. Simple linear probability estimates using the dichotomous discomfort symptom variables estimated the relationships of OZONE on eye discomfort, NO_2 and NO on chest discomfort, OZONE, HUMID, and TEMP on headache, NO_2 and NO on shortness of breath, and NO on cough. All of the above estimates were significant at $\alpha = 0.05$ or better.

The discomfort symptoms proportions by date were computed and the average levels of the air pollution variables were also computed. The proportions were used to estimate linear probability and LOGIT regressions. Comparisons of the single explanatory variable estimates to the multiple explanatory variable estimates demonstrated several differences. Statistical theory supports the multivariate as the more precise technique. Logic indicates the sigmoid LOGIT specification is consistent with the probability interpretation. The LOGIT estimates showed a statistically significant relationship of EYES, CHEST, and BREATH with OZONE. There was also a statistically significant relationship of the same discomfort symptom variables with CO. The LOGIT estimates showed an inverse relationship of EYES, CHEST, and BREATH with CO. These results were reinforced by the linear probability regressions.

SECTION 10

DATA ANALYSIS--ATHLETE PANEL

STATISTICAL DESCRIPTION OF THE ATHLETE PANEL

Members of a cross-country team at Citrus College in Azusa, California were recruited for the athlete panel. Seventeen athletes agreed to participate. All were 18 or 19 years of age, physically conditioned for distance running, and apparently free of disease. The qualifications for participation did not cover smoking; however, none of the panelists were smokers. Table 78 summarizes the composition of this panel.

TABLE 78. COMPOSITION OF THE
ATHLETE PANEL

Characteristics	Total Panel
Subjects enrolled in panel	17
Current cigarette smokers	0
Subjects under 21 years old	17
Subjects with 12 or more years of school completed	17
Race other than White	5

The comprehensive clinical examinations administered before and after the testing period and the clinical interviews held after the testing period confirmed that all of the athletes were in good health. The athlete panel was tested on 11 days over a period of seven weeks. The schedule of testing is given in Appendix L. Attendance ranged from 7 to 11 subjects, with an average daily attendance of 8. The types of data obtained from each athlete panelist are listed in Section 4 of this report. All data were included in the analysis except for heart function measures, the results of the hematological and nasal smear evaluations, the nausea symptom information, and the information on

medication. The reasons for not including the heart, blood, and nasal smear data are the same as those given for the bronchitis panel. None of the athlete panelists suffered symptoms of nausea and none took medication on any of the testing days.

Description of the Variables

The discomfort symptom variables were measured with the form shown in Appendix F. The same coding was used on the responses as in the other panels: unity for "Yes," zero for "No." The main difference between the athlete panel and the other panels was that discomfort symptom information was taken before and after the athletes subjected themselves to stress, i.e., ran a distance of at least two miles. A statistical profile of the discomfort variables is given in Table 79A.

The discomfort symptoms reported before running are indicated by placing a "1" following the variable name. For example, EYES1 is the variable name for eye discomfort reported before running. The discomfort symptoms reported after running are indicated by placing a "2" following the variable name. Thus, EYES2 denotes eye discomfort reported after running.

The proportions of the discomfort symptoms reported were extremely small for all of the discomfort variables listed. For example, only 8 percent of all responses were "Yes" to the presence of eye discomfort before running, and only 9 percent were "Yes" to eye discomfort after running. The pattern of little or no discomfort before stress and little or no change after stress is consistent for all of the discomfort variables.

Two pulmonary function variables were used in the analysis of the athlete panel. Each was measured before and after running each testing day. A profile of these variables is given in Table 79B. Maximum FVC and maximum $FEV_{1.0}$ are listed as BFVC and BFEV for the measurements made before running. Maximum FVC and maximum $FEV_{1.0}$ are listed as AFVC and AFEV for the measurements made after running. BFVC and AFVC were each taken from the best of five maneuvers. BFEV and AFEV were the highest $FEV_{1.0}$ taken from the volume-time tracings of the FVC maneuvers. The AGE and HEIGHT of each panelist were recorded as age in years and standing height in inches. These data were used to adjust the BFVC, BFEV, AFVC, and AFEV scores prior to analysis. A profile of the distances run between reporting discomfort symptoms and taking pulmonary function tests is shown in Table 79C.

The air pollution and weather variables used in this analysis are the same as those used in the asthma panel analysis. The profile of these variables is given in Table 79D. The air pollution variables were obtained as hourly averages measured in

VARIABLE: EYES1 = Eye discomfort before running

MEAN	=	0.080	RANGE	=	1.000	
VARIANCE	=	0.075	MINIMUM	=	0.000	
KURTOSIS	=	7.638	MAXIMUM	=	1.000	
STD DEV	=	0.274	VALID OBS	=	87	
SKEWNESS	=	3.121	MISSING OBS	=	0	

VARIABLE: EYES2 = Eye Discomfort after running

MEAN	=	0.092	RANGE	=	1.000
VARIANCE	=	0.084	MINIMUM	=	0.000
KURTOSIS	=	6.081	MAXIMUM	=	1.000
STD DEV	=	0.291	VALID OBS	=	87
SKEWNESS	=	2.857	MISSING OBS	=	0

VARIABLE: THROAT1 = Throat discomfort before running

MEAN	=	0.034	RANGE	=	1.000
VARIANCE	=	0.034	MINIMUM	=	0.000
KURTOSIS	=	24.350	MAXIMUM	=	1.00
STD DEV	=	0.184	VALID OBS	=	87
SKEWNESS	=	5.162	MISSING OBS	=	0

VARIABLE: THROAT2 = Throat discomfort after running

MEAN	=	0.115	RANGE	=	1.000
VARIANCE	=	0.103	MINIMUM	=	0.000
KURTOSIS	=	3.909	MAXIMUM	=	1.000
STD DEV	=	0.321	VALID OBS	=	87
SKEWNESS	=	2.443	MISSING OBS	=	0

VARIABLE: CHEST1 = Chest discomfort before running

MEAN	=	0.011	RANGE	=	1.000
VARIANCE	=	0.011	MINIMUM	=	0.000
KURTOSIS	=	83.000	MAXIMUM	=	1.000
STD DEV	=	0.107	VALID OBS	=	87
SKEWNESS	=	9.272	MISSING OBS	=	0

VARIABLE: CHEST2 = Chest discomfort after running

MEAN	=	0.092	RANGE	=	1.000
VARIANCE	=	0.084	MINIMUM	=	0.000
KURTOSIS	=	6.081	MAXIMUM	=	1.000
STD DEV	=	0.291	VALID OBS	=	87
SKEWNESS	=	2.857	MISSING OBS	=	0

VARIABLE: HEADACHE1 = Headache discomfort before running

MEAN	=	0.057	RANGE	=	1.000
VARIANCE	=	0.055	MINIMUM	=	0.000
KURTOSIS	=	12.641	MAXIMUM	=	1.000
STD DEV	=	0.234	VALID OBS	=	87
SKEWNESS	=	3.847	MISSING OBS	=	0

VARIABLE: HEADACHE2 = Headache discomfort after running

MEAN	=	0.069	RANGE	=	1.000
VARIANCE	=	0.065	MINIMUM	=	0.000
KURTOSIS	=	9.720	MAXIMUM	=	1.000
STD DEV	=	0.255	VALID OBS	=	87
SKEWNESS	=	3.442	MISSING OBS	=	0

VARIABLE: OTHER1 = Other discomfort before running

MEAN	=	0.092	RANGE	=	1.000
VARIANCE	=	0.084	MINIMUM	=	0.000
KURTOSIS	=	6.081	MAXIMUM	=	1.000
STD DEV	=	0.291	VALID OBS	=	87
SKEWNESS	=	2.857	MISSING OBS	=	0

VARIABLE: OTHER2 = Other discomfort after running

MEAN	=	0.161	RANGE	=	1.000
VARIANCE	=	0.137	MINIMUM	=	0.000
KURTOSIS	=	1.457	MAXIMUM	=	1.000
STD DEV	=	0.370	VALID OBS	=	87
SKEWNESS	=	1.867	MISSING OBS	=	0

VARIABLE: COUGH1 = Cough before running

MEAN	=	0.069	RANGE	=	1.000
VARIANCE	=	0.065	MINIMUM	=	0.000
KURTOSIS	=	9.720	MAXIMUM	=	1.000
STD DEV	=	0.255	VALID OBS	=	87
SKEWNESS	=	3.442	MISSING OBS	=	0

VARIABLE: COUGH2 = Cough after running

MEAN	=	0.069	RANGE	=	1.000
VARIANCE	=	0.065	MINIMUM	=	0.000
KURTOSIS	=	9.720	MAXIMUM	=	1.000
STD DEV	=	0.255	VALID OBS	=	87
SKEWNESS	=	3.442	MISSING OBS	=	0

VARIABLE: PHLEGM1 = Phlegm before running

MEAN	=	0.000	RANGE	=	0.000
VARIANCE	=	0.000	MINIMUM	=	0.000
KURTOSIS	=	0.000	MAXIMUM	=	0.000
STD DEV	=	0.000	VALID OBS	=	6
SKEWNESS	=	0.000	MISSING OBS	=	0

VARIABLE: PHLEGM2 = Phlegm after running

MEAN	=	0.167	RANGE	=	1.000
VARIANCE	=	0.167	MINIMUM	=	0.000
KURTOSIS	=	6.000	MAXIMUM	=	1.000
STD DEV	=	0.408	VALID OBS	=	6
SKEWNESS	=	2.449	MISSING OBS	=	0

VARIABLE: HEADACHE EARLIER = Headache earlier today

MEAN	=	0.046	RANGE	=	1.000
VARIANCE	=	0.044	MINIMUM	=	0.000
KURTOSIS	=	17.028	MAXIMUM	=	1.000
STD DEV	=	0.211	VALID OBS	=	87
SKEWNESS	=	4.386	MISSING OBS	=	0

VARIABLE: COLD = Bad cold today

MEAN	=	0.023	RANGE	=	1.000
VARIANCE	=	0.023	MINIMUM	=	0.000
KURTOSIS	=	39.006	MAXIMUM	=	1.000
STD DEV	=	0.151	VALID OBS	=	87
SKEWNESS	=	6.440	MISSING OBS	=	0

VARIABLE: BREATH = Shortness of breath today

MEAN	=	0.046	RANGE	=	1.000
VARIANCE	=	0.044	MINIMUM	=	0.000
KURTOSIS	=	17.028	MAXIMUM	=	1.000
STD DEV	=	0.211	VALID OBS	=	87
SKEWNESS	=	4.386	MISSING OBS	=	0

TABLE 79B. STATISTICAL PROFILE OF PULMONARY FUNCTION
   VARIABLES AND AGE AND HEIGHT OF ATHLETE PANELISTS
           BEFORE AND AFTER RUNNING ON 11 DAYS

VARIABLE: BFVC = Maximum FVC before running
                  (in liters x 100)

MEAN	=	494.253	RANGE	=	292.000
VARIANCE	=	4,140.726	MINIMUM	=	324.000
KURTOSIS	=	-0.612	MAXIMUM	=	616.000
STD DEV	=	64.348	VALID OBS	=	87
SKEWNESS	=	-0.321	MISSING OBS	=	0

VARIABLE: BFEV = Maximum $FEV_{1.0}$ before running
                  (in liters x 100)

MEAN	=	416.069	RANGE	=	284.000
VARIANCE	=	3,511.111	MINIMUM	=	280.000
KURTOSIS	=	0.116	MAXIMUM	=	564.000
STD DEV	=	59.255	VALID OBS	=	87
SKEWNESS	=	-0.136	MISSING OBS	=	0

VARIABLE: AFVC = Maximum FVC after running
                  (in liters x 100)

MEAN	=	489.250	RANGE	=	311.000
VARIANCE	=	3,958.744	MINIMUM	=	355.000
KURTOSIS	=	-0.342	MAXIMUM	=	666.000
STD DEV	=	62.919	VALID OBS	=	84
SKEWNESS	=	0.173	MISSING OBS	=	3

VARIABLE: AFEV = Maximum $FEV_{1.0}$ after running
                  (in liters x 100)

MEAN	=	410.738	RANGE	=	296.000
VARIANCE	=	3,253.786	MINIMUM	=	280.000
KURTOSIS	=	0.716	MAXIMUM	=	576.000
STD DEV	=	57.042	VALID OBS	=	84
SKEWNESS	=	0.273	MISSING OBS	=	3

VARIABLE: AGE = Age of panelist (in years)

RANGE	=	1	VALID OBS	=	17
MINIMUM	=	18	MISSING OBS	=	0
MAXIMUM	=	19		

VARIABLE: HEIGHT = Height of panelist (in inches)

RANGE	=	13	VALID OBS	=	17
MINIMUM	=	64	MISSING OBS	=	0
MAXIMUM	=	77		

TABLE 79C. STATISTICAL PROFILE OF DISTANCES RUN BY
ATHLETE PANELISTS ON 11 TESTING DAYS

VARIABLE: DIST = Distance run (in miles)

MEAN	=	2.092	RANGE	=	4.000
VARIANCE	=	0.364	MINIMUM	=	2.000
KURTOSIS	=	39.006	MAXIMUM	=	6.000
STD DEV	=	0.603	VALID OBS	=	87
SKEWNESS	=	6.440	MISSING OBS	=	0

TABLE 79D. STATISTICAL PROFILE OF AIR POLLUTION
VARIABLES MEASURED ON 11 ATHLETE PANEL TESITNG DAYS

VARIABLE: OZONE = Estimate for oxidant (in ppm)

MEAN	=	0.107	RANGE	=	0.260
VARIANCE	=	0.005	MINIMUM	=	0.020
KURTOSIS	=	0.416	MAXIMUM	=	0.280
STD DEV	=	0.071	VALID OBS	=	86
SKEWNESS	=	1.187	MSSING OBS	=	1

VARIABLE: CO = Carbon monoxide (in ppm/100)

MEAN	=	0.038	RANGE	=	0.040
VARIABLE	=	0.000	MINIMUM	=	0.020
KURTOSIS	=	-0.784	MAXIMUM	=	0.060
STD DEV	=	0.012	VALID OBS	=	86
SKEWNESS	=	0.558	MISSING OBS	=	1

VARIABLE: NO2 = Nitrogen dioxide (in ppm)

MEAN	=	0.076	RANGE	=	0.130
VARIANCE	=	0.001	MINIMUM	=	0.020
KURTOSIS	=	-0.572	MAXIMUM	=	0.150
STD DEV	=	0.036	VALID OBS	=	78
SKEWNESS	=	0.614	MISSING OBS	=	9

VARIABLE: NO = Nitric oxide (in ppm)

MEAN	=	0.013	RANGE	=	0.020
VARIANCE	=	0.000	MINIMUM	=	0.010
KURTOSIS	=	2.349	MAXIMUM	=	0.030
STD DEV	=	0.006	VALID OBS	=	78
SKEWNESS	=	1.912	MISSING OBS	=	9

VARIABLE: HUMID = Relative humidity (in percent)

MEAN	=	61.570	RANGE	=	25.000
VARIANCE	=	47.095	MINIMUM	=	50.000
KURTOSIS	=	0.403	MAXIMUM	=	75.000
STD DEV	=	6.863	VALID OBS	=	86
SKEWNESS	=	0.127	MISSING OBS	=	1

VARIABLE: TEMP = Temperature (in degrees
Fahrenheit)

MEAN	=	73.733	RANGE	=	43.000
VARIANCE	=	80.575	MINIMUM	=	52.000
KURTOSIS	=	0.912	MAXIMUM	=	95.000
STD DEV	=	8.976	VALID OBS	=	86
SKEWNESS	=	0.271	MISSING OBS	=	1

ppm (CO in ppm/100). Relative humidity was estimated by hour and expressed in percent. A discussion on how the estimates were made is given in the paragraphs of Section 7 which describe the variables used in the asthma panel analysis. Temperature was obtained as hourly averages measured in degrees Fahrenheit.

Weighted averages of exposure to air pollutant, humidity, and temperature levels were used in the analysis of the athlete panel. As in the analysis of the asthma panel, the hour at which each panelist reported for testing was noted and the aerometric values for that hour were included in the weighted average for that day.

CORRELATION ANALYSIS

As in the other panels, Pearson and non-parametric correlation analyses were applied to the data collected from this panel. The results are highlighted in the following tables.

Pearson Correlation

The Pearson correlation coefficients for the athlete panel are reported in Tables 80 and 81. Table 80 reports the coefficients for the air pollution variables with the discomfort symptoms and pulmonary function results before running. Table 81 reports the coefficients after running. Before running, the only variables which have significant correlations are: EYES1 with OZONE and CO, THROAT1 with HUMID and TEMP, and OTHER1 with OZONE. None of the other pairs have significant correlations better than $\alpha = 0.10$. After running, the only variables with significant correlations are: EYES2 with OZONE, HEADACHE2 with OZONE, and OTHER2 with TEMP. None of the other pairs have significant correlations.

Non-Parametric Correlations

The non-parametric correlation coefficients, Spearman's R_s and Kendall's τ, were computed between the qualitative discomfort symptoms and the air monitoring data. The Spearman and Kendall coefficient variables before running are reported in Table 82 and 83, respectively. The results tend to confirm the Pearson correlations. Looking at Table 82, only EYES1 with OZONE, EYES1 with CO, and OTHER1 with OZONE are significant at a level of $\alpha = 0.05$ or better before running. In Table 83, examination of the air pollution variables with the discomfort symptom variables results in non-parametric correlations significant at $\alpha = 0.05$ or better for EYES1 with OZONE, EYES1 with CO, THROAT1 with HUMID, and OTHER1 with OZONE.

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TABLE 80. PEARSON CORRELATION COEFFICIENTS FOR THE ATHLETE PANEL BEFORE RUNNING

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES1	0.52***	0.25**	-0.07	-0.15	0.10	0.02
THROAT1	-0.05	-0.13	-0.07	-0.10	-0.21*	0.20*
CHEST1	-0.01	-0.08	-0.08	-0.06	0.01	0.09
HEADACHE1	0.15	0.11	-0.04	-0.04	0.11	-0.14
OTHER1	0.28***	0.14	0.01	-0.08	-0.12	0.09
BREATH1	0.03	-0.02	-0.08	-0.02	-0.08	0.06
COUGH1	-0.01	0.12	0.05	0.22	-0.07	0.05
PHLEGM1	0.01	-0.12	-0.05	-0.22	0.07	-0.05
HEADACHE EARLIER	0.01	0.12	0.01	-0.02	0.12	-0.17
BFVC	0.01	0.01	0.01	0.07	-0.03	-0.10
BFEV	0.02	-0.06	-0.04	-0.01	-0.03	-0.06

*Significant at α = 0.10
**Significant at α = 0.05
***Significant at α = 0.01

TABLE 81. PEARSON CORRELATION COEFFICIENTS FOR THE ATHLETE PANEL AFTER RUNNING

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES2	0.45***	0.18	-0.04	-0.15	0.10	0.09
THROAT2	0.14	0.08	-0.07	-0.04	0.10	-0.05
CHEST2	0.07	0.01	0.01	0.04	0.17	-0.01
HEADACHE2	0.23**	0.15	-0.07	0.02	0.02	-0.08
OTHER2	-0.06	-0.18	-0.10	-0.01	0.15	-0.19*
COUGH2	0.10	0.15	-0.02	0.02	0.10	-0.01
PHLEGM2	-0.10	-0.11	0.06	-0.03	-0.09	-0.07
AFVC	-0.06	0.03	0.02	0.11	-0.03	-0.07
AFEV	-0.03	0.01	0.00	0.10	-0.03	-0.02

*Significant at α = 0.10
**Significant at α = 0.05
***Significant at α = 0.01

TABLE 82. SPEARMAN CORRELATION COEFFICIENTS FOR THE ATHLETE PANEL BEFORE RUNNING

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES1	0.40***	0.25***	-0.00	-0.16*	0.10	0.04
THROAT1	-0.00	-0.14*	-0.09	-0.10	-0.22**	0.20**
CHEST1	0.05	-0.08	-0.09	-0.06	0.01	0.13
HEADACHE1	0.09	0.11	-0.03	-0.02	0.11	-0.13
OTHER1	0.18**	0.12	0.04	-0.06	-0.12	0.16*
BREATH1	-0.05	-0.04	-0.08	0.01	-0.08	0.10
COUGH1	-0.07	0.11	0.04	0.15	-0.07	0.09
PHLEGM1	0.07	-0.11	-0.04	-0.15*	0.07	-0.09
HEADACHE EARLIER	-0.04	0.13	0.01	0.01	0.12	-0.16*

*Significant at $\alpha = 0.10$
**Significant at $\alpha = 0.05$
***Significant at $\alpha = 0.01$

TABLE 83. KENDALL CORRELATION COEFFICIENTS FOR THE ATHLETE PANEL BEFORE RUNNING

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES1	0.34***	0.23**	-0.01	-0.16*	0.10	0.03
THROAT1	-0.01	-0.13*	-0.07	-0.10	-0.21**	0.17
CHEST1	0.04	-0.07	-0.08	-0.06	0.01	0.11
HEADACHE1	0.08	0.10	-0.03	-0.02	0.11	-0.11
OTHER1	0.15**	0.11	0.03	-0.06	-0.11	0.13*
BREATH1	-0.04	-0.03	-0.07	0.01	-0.08	0.09
COUGH1	-0.06	0.10	0.03	0.15	-0.07	0.07
PHLEGM1	0.06	-0.10	-0.03	-0.15	0.07	-0.07
HEADACHE EARLIER	-0.04	0.11	0.01	0.01	0.12	-0.13*

*Significant at α = 0.10
**Significant at α = 0.05
***Significant at α = 0.01

The non-parametric correlations for the discomfort symptoms present after running are reported in Tables 84 and 85. The correlation coefficients which are significant at $\alpha = 0.05$ or better are those for EYES 2 with OZONE and CO, OTHER2 with CO, and PHLEGM2 with TEMP. The only two non-parametric correlations which are significant both before and after running are EYES1 and EYES2 with OZONE and CO.

MEASURES OF ASSOCIATION BETWEEN VARIABLES

Simple linear regressions and linear probability analyses were performed on the health data collected from the athlete panel. In addition, contingency tables were constructed and χ^2 tests were applied between the FVC and $FEV_{1.0}$ variables and the air pollution variables. The results are reported below.

Simple Linear Regressions of FVC and $FEV_{1.0}$

FVC and $FEV_{1.0}$ before and after running were regressed on the air pollution data for OZONE, CO, NO_2, NO, HUMID, and TEMP. The results indicate no significant linear relationship between either FVC or $FEV_{1.0}$ on the level of air pollution variables for the athlete panel. Scattergrams were examined to see if there were any discernable non-linear relationships between FVC or $FEV_{1.0}$ and the level of air pollution for this panel. None were found.

Simple linear regression equations were computed with FVC or $FEV_{1.0}$ before and after running as the dependent variables. The explanatory variables were the air pollution variables. The test of the hypothesis of a significant linear relationship between the dependent and independent variable involved a two-tailed test that R is significantly different from zero. That hypothesis could not be rejected at $\alpha = 0.10$ or greater levels of significance for any of the regressions.

Contingency Tables Between the Pulmonary Function and the Air Pollution Variables

A series of contingency tables were constructed using FVC and $FEV_{1.0}$ before and after running with the air pollution variables. FVC (in liters x 100) was divided into two classes: $0 \leq FVC < 500$ and $500 \leq FVC$. Likewise, $FEV_{1.0}$ (in liters x 100) was divided into to classes: $0 \leq FEV_{1.0} < 400$ and $400 \leq FEV_{1.0}$. The classes for the air pollution variables are the same as those used to analyze the asthma panel. All of the tables are (2x2) and have critical values of the χ^2 statistic of $\chi^2 = 6.63$ at $\alpha = 0.01$, $\chi^2 = 3.84$ at $\alpha = 0.05$, and $\chi^2 = 2.70$ at $\alpha = 0.10$. Computed χ^2 values greater than these critical values lead to a rejection of the hypothesis of independence between the variable classes.

TABLE 84. SPEARMAN CORRELATION COEFFICIENTS FOR THE ATHLETE PANEL AFTER RUNNING

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES2	0.40***	0.18**	0.05	-0.16*	0.10	0.07
THROAT2	0.07	0.06	-0.12	-0.01	0.10	-0.02
CHEST2	0.08	0.01	0.00	0.03	0.17*	-0.03
HEADACHE2	0.14	0.14*	-0.03	-0.02	0.03	-0.04
OTHER2	-0.05	-0.19**	-0.12	-0.03	0.15*	-0.17*
COUGH2	0.09	0.11	-0.04	0.06	0.11	0.07
PHLEGM2	-0.16*	-0.08	0.09	-0.08	-0.10	-0.18**

*Significant at α = 0.10
**Significant at α = 0.05
***Significant at α = 0.01

TABLE 85. KENDALL CORRELATION COEFFICIENTS FOR THE ATHLETE PANEL AFTER RUNNING

	OZONE	CO	NO2	NO	HUMID	TEMP
EYES2	0.34***	0.17**	0.04	-0.16*	0.10	0.06
THROAT2	0.06	0.05	-0.10	-0.01	0.09	-0.02
CHEST2	0.06	0.01	0.00	0.03	0.17*	-0.02
HEADACHE2	0.12	0.13	-0.02	-0.02	0.03	-0.03
OTHER2	-0.04	-0.18**	-0.10	-0.03	0.15*	-0.14*
COUGH2	0.08	0.10	-0.04	0.06	0.10	0.06
PHLEGM2	-0.13*	-0.07	0.07	-0.08	-0.10	-0.15**

 *Significant at α = 0.10
 **Significant at α = 0.05
***Significant at α = 0.01

The results for FVC before and after running with the air pollution variables OZONE, CO, NO_2, and NO were calculated. None of the computed χ^2 values were significant at $\alpha = 0.10$ or better. The results for $FEV_{1.0}$ before and after running with the air pollution variables were also calculated. Again, none of the χ^2 values were significant. It is not possible to reject the hypothesis of independence between the FVC or $FEV_{1.0}$ variables and the air pollution variables either before or after running. The indication is that the athlete panelists were relatively insensitive to the levels of air pollution measured during the survey.

A separate set of contingency tables was constructed between the variable COLD and the discomfort symptoms. The null hypothesis was that reporting a discomfort symptom is independent of having a cold. The hypothesis of independence between THROAT1 and COLD is rejected at a level of significance of $\alpha = 0.10$. The hypothesis is rejected at $\alpha = 0.01$ for CHEST1 with COLD. None of the other discomfort symptoms before running show any association with having a cold. After running, none of the discomfort symptoms show any association with having a cold; thus, the hypothesis of independence between the discomfort symptoms and having a cold cannot be rejected.

Linear Probability Model

Linear probability functions were estimated using the qualitative discomfort symptoms for the athlete panel as the dependent variables. Regressions were performed for the dependent variables both before and after running. The functions which were significant at $\alpha = 0.10$ or better are:

$$\text{Prob(EYES1)} = -0.136 + 2.040(\text{OZONE}) \quad R^2 = 0.274$$

$$\text{Prob(EYES1)} = -0.137 + 5.679(\text{CO}) \quad R^2 = 0.063$$

$$\text{Prob(THROAT1)} = 0.384 - 0.006(\text{HUMID}) \quad R^2 = 0.044$$

$$\text{Prob(THROAT1)} = -0.264 + 0.004(\text{TEMP}) \quad R^2 = 0.039$$

$$\text{Prob(EYES2)} = -0.108 + 1.882(\text{OZONE}) \quad R^2 = 0.207$$

$$\text{Prob(OTHER2)} = 0.758 - 0.008(\text{TEMP}) \quad R^2 = 0.038$$

None of the other discomfort symptoms showed any association with the air pollution variables at $\alpha = 0.10$ or better.

The estimated linear probability functions with eye discomfort, both before and after running with OZONE as the explanatory variable, have high R^2 values for regressions with a dichotomous dependent variable. OZONE explains 27 percent of the variance in EYES1. OZONE also explains almost 21 percent of the variance in EYES2. CO explains 6 percent of the variance in EYES1. The only other discomfort symptoms which show significant relationships in the linear probability specification are THROAT1 with HUMID, THROAT1 with TEMP, and OTHER2 with TEMP. OTHER2 is inversely related to TEMP with almost 4 percent of the variance explained.

PAIRED DIFFERENCE TEST OF MEANS OF PULMONARY FUNCTION VARIABLES

An analysis of paired differences was possible for the athlete panel, where the same individuals were measured before and after the planned exercise of running a distance of at least two miles. Both FVC and $FEV_{1.0}$ were measured before and after running for each athlete. The purpose of pairing was to reduce extraneous influences on the variable (either FVC or FEV) being measured. Pairing reduced subject-to-subject variability.

The paired difference variable was formed by computing the difference between mean BFVC and AFVC scores. Also, the paired difference between mean BFEV and AFEV scores was computed. The null hypothesis in each case was that the mean of the difference is equal to zero, H_o: $\mu_d = 0$. The alternative hypothesis was that H_A: $\mu_d > 0$; i.e., FVC and $FEV_{1.0}$ scores were expected to decline as a result of running. If the null hypothesis is rejected, then the data supports the alternative hypothesis of a decline in the measured variable. Since the alternative hypothesis was directional, a one-tailed test was appropriate.

The results of the paired difference test for FVC and $FEV_{1.0}$ for the athletes are reported in Table 86. Neither of the t-values are large enough to reject the null hypothesis at a level of significance of $\alpha = 0.05$. The implication is that no significant decrease in either FVC or $FEV_{1.0}$ occurred as a result of running.

OVERALL SUMMARY OF THE ATHLETE PANEL DATA ANALYSIS

Very few significant results were obtained from the athlete panel. One explanation for this outcome is that the ambient concentrations of air pollution on the 11 days when the panel was tested were not high enough to cause measurable biochemical and

TABLE 86. PAIRED DIFFERENCE TEST OF MEAN FVC AND MEAN FEV
(BOTH IN LITERS x 100) BEORE AND AFTER RUNNING

Variable	Mean	Standard Deviation	(Difference) Mean	Standard Deviation	t Value	1-Tail Probability
BFVC	492.3690	64.538				
AFVC	489.2500	62.919	3.1190	25.723	1.11	0.135
BFEV	414.5000	59.275				
AFEV	410.7381	57.042	3.7619	22.490	1.53	0.065

Note: Degrees of freedom = 83

physiologic responses in the panel members. An equally plausible explanation, however, is that the data collection was centered on the wrong variables and/or was conducted under the wrong circumstances.

It was probably a mistake to collect data during practice instead of competition and to depend entirely on health data instead of both health and performance data to assess the impact of air pollution. The results of a study conducted in the Los Angeles community of San Marino in the early to mid-1960's demonstrated the importance of including performance variables.* The study involved high school long distance runners. Relationships were found between concentrations of photochemical air pollution one hour before races and the performance of the runners (i.e., group running times) clocked during the races.

In the present study, there was no assurance that the members of the athlete panel achieved maximal exercise on any of the testing days. Maximal exercise could be assumed if the members of the panel had been running in competition against teams from other schools. It cannot be assumed under non-competitive, practice conditions. In addition, the runners' times were not consistently recorded, so an attempt to relate concentrations of air pollution to performance was not possible.

A few results were obtained which showed relationships between discomfort symptoms and the aerometric variables. Correlation analysis indicated that there was a direct relationship between eye discomfort, both before and after running, and OZONE. That relationship was upheld by linear probability estimates. The linear probability functions for both EYES1 and EYES2 with OZONE, were highly significant with coefficients of determination above 20 percent. Correlation analysis also indicated a direct relationship between eye discomfort before running and CO. Again, the relationship was upheld by the linear probability estimate. None of the other variables (discomfort symptoms, maximum $FEV_{1.0}$, or maximum FVC) measured in connection with the athlete panel showed any significant relationship with respect to the air pollution variables. Throat discomfort before running showed a statistically significant relationship with weather variables HUMID and TEMP, and other discomfort reported after running was estimated as being significantly influenced by TEMP.

---

*W.S. Wayne, P.F. Wehrle, and R.E. Carroll. "Oxidant Air Pollution and Athlete Performance," Journal of the American Medical Association, 199(12), March 20, 1967, 901-904.

APPENDIX A

INTERVIEWER INSTRUCTIONS

INTERVIEWER INSTRUCTIONS

BACKGROUND

The Four Panel Study is funded by the EPA and is similar in some ways to previous studies we have conducted for the EPA and very different in others. The purpose of the study is to measure how the environment affects health on days when pollution is unusually high. The study is <u>not</u> designed to evaluate the commulative effect of several years of exposure.

Four panels will be used in the study: athletes, asthmatics, bronchitics, and healthy outdoor workers. CIC is managing the study and will be assisted by the Lung Association of Los Angeles County, the University of California, Riverside, and Rockwell International. Your task as interviewers is to recruit people for the Asthma and Bronchitis panels. These interviews for the Four Panel Study are designed to determine whether the person qualifies for the panel (medical condition, age, etc.) and whether he is willing and able to participate. All other information about the panelist will be obtained in interviews conducted by the Lung Association during the test periods.

The Four Panel Study differs from previous studies in another way because it is a pilot study for testing new techniques for gathering information about health effects. This means that CIC is making out the schedule, designing the questionnaires, and writing instructions for interviewing and testing. We will be the first group to do these panel studies, and we may find that some instructions and procedures will not work and will have to be changed. YOU SHOULD NOT MAKE CHANGES ON YOUR OWN, BUT SHOULD TELL YOUR TEAM LEADER ABOUT PROBLEMS YOU ENCOUNTER.

The study will be conducted in portions of Azusa, Covina, and Glendora. A street map of the study area showing exactly where we will be working will be given to you. We have tried to choose an area that will have essentially the same environment; this means that we do not go up into the hills, as the environment changes there.

We will be recruiting asthmatics and bronchitics at the same time, so you will have to be familiar with two studies instead of one. You will administer a short, simple questionnaire

to those who have asthma or bronchitis for the purpose of allowing us to judge whether they are truly qualified. At present, we are assuming that we may have to ring every doorbell in the entire study area to recruit enough asthmatics. You must try to do such a good job of selling the study that every qualified panelist will want to participate.

INTERVIEW ASSIGNMENTS

Each day your team leader will give you a set of Interviewer Record sheets like the one attached to these instructions. Only the street name and city will be filled in; you will fill in house numbers as you make the interviews. A record should be made even if you ring the bell and no one answers. An example of a completed Interviewer Record sheet is also attached.

At the end of the day, check over your Interviewer Record sheets to make sure that they are legible. Mark in some conspicuous way all cases where you have promised callbacks. Make sure your team leader sees these. Give all Interviewer Records to your team leader every day.

INITIAL CONTACT

The purpose of this initial contact is to determine as efficiently as possible whether any adult member of the household has chronic bronchitis or asthma. This is not a statistical survey, so we do not need to worry about leading the respondent and biasing the results. The following is suggested:

> "Hello. I'm _____ from Copley International Corporation. We are trying to locate adults with chronic bronchitis or asthma who would be interested in helping with a study to see how the environment affects their health. This study is being sponsored by the federal government. Does anyone in this household qualify? Do you know of anyone else who might be interested?"

If the respondent is a potential panelist, proceed as directed in the PANEL INTERVIEW section of these instructions. If the respondent wants more information to decide whether some other member of the household qualifies, proceed as follows:

- If asked, "What is asthma?," explain that the main criterion is that he has episodes of shortness of breath and wheezing in the chest, and that a doctor has diagnosed it as asthma.

- If asked, "What is chronic bronchitis?," explain
  that this is a persistent cough that raises phlegm
  from the chest that may or may not have been called
  bronchitis by a doctor.

- If asked, "What do you mean by adult?," explain that
  asthmatics must be 30-45 years old, while bronchitics
  must be 35-55 years old.

If a prospective panelist is not at home, try to make an ap-
pointment for an interview at some time when the prospective
panelist is available--preferably the following day.

PANEL INTERVIEW

   The first step in conducting the interview is to determine
whether the respondent has asthma or bronchitis. Select the in-
terview questionnaire that corresponds to the respondent's con-
dition. Find out whether the respondent is the proper age for
the panel. IF HE IS NOT IN THE RIGHT AGE BRACKET, TERMINATE THE
INTERVIEW AND DO NOT FILL OUT THE QUESTIONNAIRE.

   The Asthma Panel Questionnaire is relatively straightfor-
ward. The answer to Question 1 should always be "Yes" in this
survey. Som respondents may not understand Question 4a, "Short-
ness of breath" so you may want to substitute one of the follow-
ing:

- "Difficulty taking in enough breath"

- "Difficulty breathing out the air that you take in"

After you have completed the first five questions, stop and ex-
plain the study to the respondent. Use the Memo to Asthma
Panelist for reference, and emphasize that he will receive a
chest X-ray and other lung tests and will be notified if any
medical problems are discovered. Also emphasize that his par-
ticipation will only be for two weeks (ten weekdays) plus two
days.

   After you have explained the study, fill out the bottom
portion of the questionnaire. DO NOT encourage the respondent
to specify a defininte time of day for his appointment, such as
3:15 or 4:30, but try for general times, such as "afternoon" or
"between 4 and 6 p.m.," etc. Under "Comments" write down any
additional information that relates to the availability for
testing or the mechanics of getting him to the test location.
If a respondent refuses to participate, write down his reason
for refusing.

For every respondent who agrees to participate, fill out a
Memo to Asthma Panelist and leave it with him. DO NOT LEAVE
THIS MEMO UNLESS THE PERSON AGREES TO BE A PANELIST. Before you
leave, tell the respondent that there is a possibility that he
might not be selected for the study. Usually this is because he
hasn't had enough attacks or because his asthma began when he
was a child instead of an adult. The memo explains the time
schedule for notification of panelists. BEFORE YOU LEAVE, ASK
THE RESPONDENT IF HE KNOWS ANYONE IN THE AREA WHO MIGHT BE A
CANDIDATE FOR EITHER OF THE PANELS.

The Bronchitis Panel Questionnaire is also relatively
straightforward. The biggest problem will probably be with
Question 1 because chronic bronchitis is not always diagnosed as
such by a doctor. You may wish to ask Questions 2, 3, and 4 to
help the respondent make up his mind. If he answers "Yes" to at
least two of these questions, and if he has had the condition
for several years, he is eligible for the study. At this point,
stop and explain the study, using the Memo to Bronchitis
Panelist as a reference. Do your very best low-key selling job
here. Emphasize that he will receive a full chest X-ray and
electrocardiogram, and will be notified if any medical problems
are found. Be sure to tell him that a small blood sample will
be taken at 4 of the 11 examinations. Don't overemphasize this,
but you may want to assure him that the Breathmobile technicians
take pride in making the procedure painless. If you have to,
you can tell the respondent that we will not repeat any part of
the examination that causes him excessive discomfort or dis-
tress. You may also want to explain that the dates for the
examinations cannot be set in advance because they will depend
on the weather. You should also remind the women that they will
have to disrobe partially for the electrocardiogram. You will
be supplied with a memo containing suggestions for those who may
not want to disrobe.

After you have explained the study, fill out the rest of
the quesionnarie which deals with scheduling and transportation.
This is self-explanatory. If the respondent refuses to partici-
pate, write down the reason.

For every respondent who agrees to participate, fill out a
Memo to Bronchitis Panelist and leave it with him. DO NOT LEAVE
THIS MEMO UNLESS THE PERSON AGREES TO BE A PANELIST. Before you
leave, tell the respondent that there is a possibility that he
might not be selected for the study. This could happen because
we are trying to recruit a panel with equal numbers of men and
women spread uniformly over the study area. The memo explains
the time schedule for notification of panelists. BEFORE YOU
LEAVE, ASK THE RESPONDENT IF HE KNOWS ANYONE IN THE AREA WHO
MIGHT BE A CANDIDATE FOR EITHER OF THE PANELS.

MISCELLANEOUS

If you should interview an individual who seems genuinely interested in being a panelist but wants to discuss it with his doctor first, try to accommodate him. If you think if appropriate, you may tell the individual that his doctor may call Dr. Stanley Rokaw at the Lung Association of Los Angeles County, telephone 213/483-3220, for more information. DR. ROKAW WILL NOT TALK TO INDIVIDUAL RESPONDENTS--ONLY TO THEIR DOCTORS.

The first time an individual visits the Breathmobile, he will be given additional information about the tests and will have a chance to ask questions. When he is satisfied that he understands the procedures, he will be asked to sign a consent form. He can, of course, refuse to consent even at this late date, but we hope this won't happen.

INTERVIEWER RECORD

_____   _____   _____
    (street)   (city)   (interviewer)

House Number	Date/Time #1	Date/Time #2	Contact?	Eligible Panelist?	Asth-matic	Bron-chitic	Comments (quest. completed, callback, refused, etc.)
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	

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INTERVIEWER RECORD

__Main__   __Azusa__   __F. Panel__
(street)   (city)   (interviewer)

House Number	Date/Time* #1	#2**	Contact?***	Eligible Panelist?	Asth-matic	Bron-chitic	Comments (quest. completed, callback, refused, etc.)
318	7/30 11³⁰		No (Yes)	(No) Yes	A	B	
322 Apt. 1	" 11³⁰		(No) Yes	No Yes	A	B	
322 Apt. 2	" 11³⁰		(No) Yes	No Yes	A	B	Parents work – home after 5³⁰
322 Apt. 3	" 11⁴⁵		No (Yes)	No (Yes)	A	(B)	Q completed – accepted
322 Apt. 4	" 11⁴⁵		No (Yes)	maybe No Yes	(A)	B	Husband works – call 279·1132 for evening interview
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	* Approximate times are okay.
			No Yes	No Yes	A	B	** This column to be used if we try to recontact those who weren't home.
			No Yes	No Yes	A	B	*** Circle "Yes" if you talk to someone who knows about the family health.
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	
			No Yes	No Yes	A	B	

ASTHMA PANEL QUESTIONNAIRE

Mr.
Mrs. _____
Miss   (last)   (first)

Start Time_____

Finish Time_____

Address_____
            (number)   (street)

_____
Occupation

_____
(city)

_____
Work Location

Telephone_____ _____
            (home)   (work)

_____
Birthdate

1. Have you ever had ASTHMA?   Yes ☐   No ☐

    (IF "Yes" TO 1, ASK:) Has a doctor told you this?   Yes ☐   No ☐   NA ☐

    (IF "Yes" TO 1, ASK:) Are you now taking medicine for this?   Yes ☐   No ☐   NA ☐

2. How old were you when your asthma first began?   _____ years

3. About how many asthma attacks have you had within the past year?   _____ attacks

4. When you have an asthma attack, do you usually have:

    a. Shortness of breath?   Yes ☐   No ☐

    b. Wheezing in the chest?   Yes ☐   No ☐

    c. Fever?   Yes ☐   No ☐

    d. Increased sputum or phlegm condition?   Yes ☐   No ☐

5. What provokes your asthma attacks?

    Dusts or pollens ☐   Emotions ☐

    Infection ☐   Don't know ☐

6. Do you smoke cigarettes?   Yes ☐   No ☐

Subject agrees to participate: Yes ☐   No ☐

Times NOT available for testing: Sept. 9-20 ☐   Oct. 7-18 ☐

    Sept. 23-Oct. 4 ☐   Oct. 21-Nov. 1 ☐

Preferred time of day for appointment:_____

Preferred transportation: Subject's car ☐   Our car ☐

Comments:_____

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MEMORANDUM

TO: Volunteer for Asthma Panel

FROM: Copley International Corporation
           12511 Brookhurst Street, Garden Grove, California 92640
           Telephone: 714/539-7751

SUBJECT: Study Plans, 1974

Sometime before October 9, 1974, you will be notified (by mail or telephone) whether you have been chosen to be a member of the Asthma Panel. As a panelist you have volunteered to do the following:

1. Report to a test location in Covina (address to be supplied later) at an appointed time on ten consecutive weekdays. Your appointment will be at the same time each day, and transportation will be supplied, if necessary.

2. Each day, blow into a machine that will measure how big a breath you can take. Answer a few questions about the kinds of discomfort you feel. The test will take about five minutes and will be administered by Copley International Corporation personnel.

3. On two days, one before and one after your two-week test period, go to the Breathmobile and blow into several machines that will do a more thorough job of measuring your lung function. These tests will take about 10 minutes. The Breathmobile will be located in the Covina area. You will be contacted by telephone about specific times for these appointments.

4. On one of these visits to the Breathmobile, complete a clinical interview questionnaire that includes questions about your present symptoms, past health, smoking habits, and exposures to dust or fumes. Have a full chest X-ray taken during this visit.

You and your doctor will be notified if the tests indicate that you have any abnormal condition that might require treatment. The effects of the environment on your condition will not be known until we have studied many people. When the results are published, we will try to see that you receive a copy.

Thank you for your help.

You have indicated that you will not be available for testing during:

        Sept. 9-20   ☐   Oct. 7-18   ☐

        Sept. 23-Oct. 4 ☐   Oct. 21-Nov. 1 ☐

You have indicated _____ as a preferred
time of day for your appointment.

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BRONCHITIS PANEL QUESTIONNAIRE

Mr.

Mrs._____

Miss   (last)   (first)

Address_____

                (number)   (street)

_____
                        (city)

Telephone_____   _____

                (home)   (work)

Start Time_____

Finish Time_____

_____
            Occupation

_____
            Work Location

_____
            Birthdate

1. Have you ever had CHRONIC BRONCHITIS? Yes ☐ No ☐

    (IF "Yes" TO 1, ASK:) Has a doctor told you that you NOW have this? Yes ☐ No ☐ NA ☐

    (IF "Yes" TO 1, ASK:) Are you now taking medicine for this? Yes ☐ No ☐ NA ☐

2. Do you cough first thing in the morning (when you get up) on more than 50 days in a year? Yes ☐ No ☐

    (IF "Yes" TO 2, ASK:) How many years have you coughed like this? _____ years

3. Do you bring up any phlegm from your chest first thing in the morning (when you get up) on more than 50 days in a year? Yes ☐ No ☐

    (IF "Yes" TO 3, ASK:) How many years have you brought up phlegm like this? _____ years

4. Do you bring up any phlegm from your chest later in the day on more than 50 days in a year? Yes ☐ No ☐

    (IF "Yes" TO 4, ASK:) How many years have you brought up phlegm like this? _____ years

5. Do you smoke cigarettes? Yes ☐ No ☐

    Subject agrees to participate: Yes ☐ No ☐

    Preferred transportation: Subject's car ☐   Our car ☐

over.../

Page 1

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Times available for testing:

	12	1	2	3	4	5	6	7	8
M									
Tu									
W									
Th									
F									

Is there any period during September and October when subject
expects to be away? _____

Comments: _____

_____

_____

_____

Page 2

MEMORANDUM ·

TO: Volunteer for Bronchitis Panel

FROM: Copley International Corporation
           12511 Brookhurst Street, Garden Grove, California 92640
           Telephone: 714/539-7751

SUBJECT: Study Plans, 1974

Sometime before September 6, 1974, you will be notified (by mail or telephone) whether you have been chosen to be a member of the Bronchitis Panel. As a panelist, you have volunteered to do the following:

1.   On eleven (11) occasions between September 3 and November 8, 1974, receive a telephone call notifying you to keep an appointment at the Breathmobile the following day. All appointments will be scheduled on weekdays between 12:00 noon and 7:50 p.m.

2.   Present yourself at the Breathmobile at the appointed time (or be ready for our vehicle to pick you up if we have agreed to do so). The Breathmobile will be located in the Covina area and you will be told of its exact location later.

3.   Allow the Breathmobile staff to perform a series of tests that will take about 20 minutes and will require you to (1) blow into several machines to see how well your lungs function; (2) have your pulse, blood pressure, and an electrocardiogram taken; (3) have a swab taken of material from your nose; and (4) have a small blood sample taken on 4 of the 11 visits.

4.   On one of your eleven visits to the Breathmobile, complete a clinical interview questionnaire that includes questions about your present symptoms, past health, smoking habits, and exposures to dust or fumes. Have a full chest X-ray taken during this visit.

You and your doctor will be notified if the tests indicate that you have any abnormal condition that might require treatment. The effects of the environment on your condition will not be known until we have studied many people. When the results are published, we will try to see that you receive a copy.

Thank you for your help.

You have indicated that you are available for testing at the following times:

_____

_____

REMINDER TO FEMALE BRONCHITIS PANELISTS

In preparation for the electrocardiogram (heart test) at the Breathmobile, you will be asked to partially disrobe so that your chest and legs are bare. You will be covered by a sheet or gown during the test. If you would be offended or embarrassed by disrobing in the presence of the Breathmobile's medical personnel, we suggest that you wear a two-piece bathing suit which you can leave on for the test. We also suggest that you do not wear panty hose; if you do, you must remove them for the test.

APPENDIX B

INSTRUCTIONS TO PANELISTS

COPLEY INTERNATIONAL CORPORATION

Economic Research • Corporate Planning • Systems Engineering • Management Services

August 28, 1974

Dear Panelist:

Thank you for agreeing to participate in our study of bronchitics in the Covina-Azusa area. You have been chosen as a panelist on one of our upcoming panels and we appreciate the time and effort which will be required on your part to help us with this important research project.

On September 3, you will receive a telephone call telling you of your first appointment to be scheduled for September 4 or 5. Transportation arrangements, if necessary, will also be made at that time. Later, as our interviewer told you, you will be called and asked to come in for tests on 10 separate occasions. In each case the testing will be done on a weekday and you will be called a day in advance. All testing will be done at the Breathmobile which will be located at Dalton Community Park (see enclosed map). Your first appointment at the Breathmobile will take about 20 minutes, with the subsequent visits taking approximately 10 minutes each.

Please save this letter and post it as a reminder to you of your appointments. After your telephone call on September 3, write your appointment times and dates on the appropriate line below. You will keep the same time for all of your visits unless other arrangements have been made. It is important that you be prompt, as we will be testing many people and do not wish to keep anyone waiting. If one of our drivers will be picking you up, please be ready 15 minutes before your scheduled appointment time.
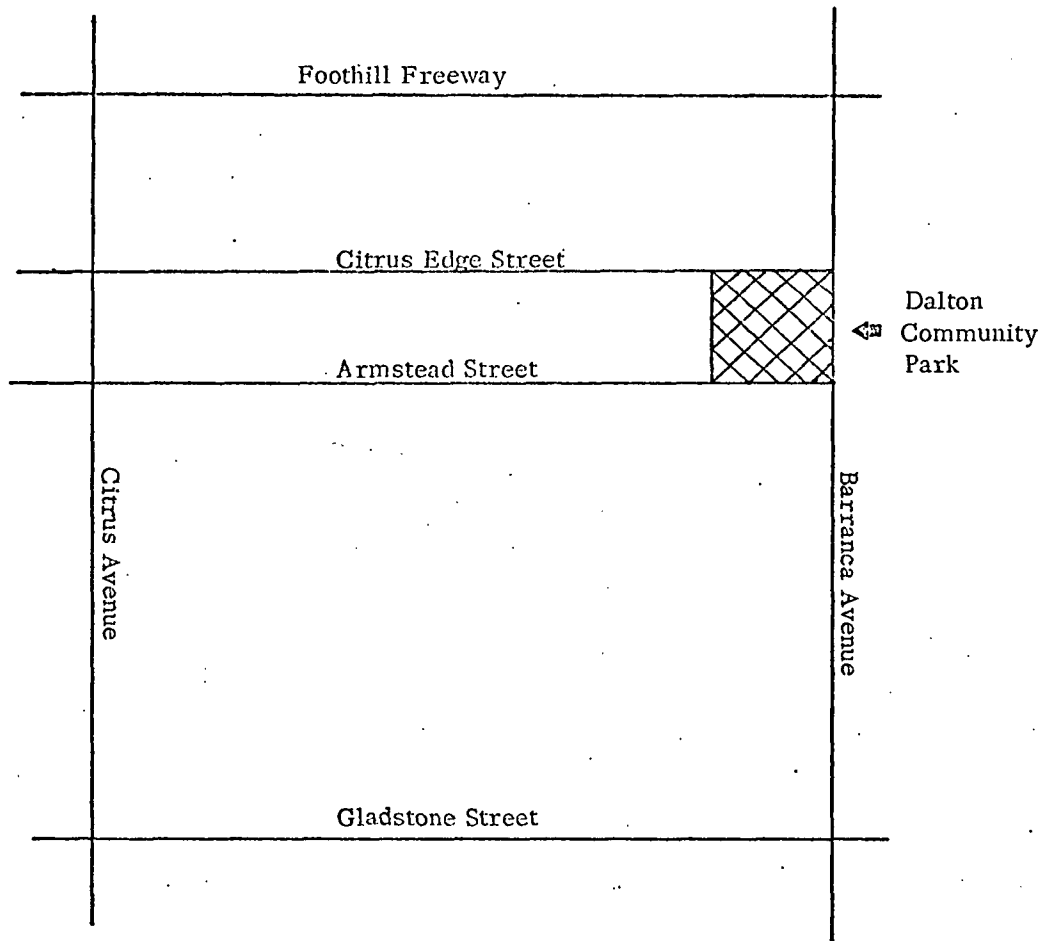
Once again thank you for your cooperation. We look forward to working with you very soon.

Sincerely,

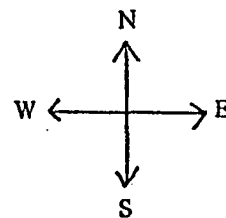Katherine W. Wilson
Project Director

Initial Breathmobile appointment: _____, 1974, at _____ a.m./p.m.

BREATHMOBILE LOCATION

Breathmobile located at:

Dalton Community Park
(formerly Barranca Park)
18867 E. Armstead
Azusa, California

APPENDIX C

ELECTROCARDIOGRAPH DATA FORM

ELECTROCARDIOGRAPH ANALYSIS

LUNG ASSOCIATION
OF
LOS ANGELES COUNTY

I. D. # _____

Name _____

Date _____ Time _____ | Time _____

Rate: Atrial _____ | _____

        Ventricular _____ | _____

Mechanism _____ | _____

Axis Deviation _____ | _____

P-R Interval _____ | _____

P-Waves Deflections _____ | _____

QRS Complexes _____ | _____

T-Waves _____ | _____

S-T Segments _____ | _____

Others _____ | _____

_____ | _____

_____ | _____

Conclusions: _____ | _____

_____ | _____

_____ | _____

_____ | _____

_____ | _____

_____ | _____

_____ | _____

INTERPRETATION BY:_____

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APPENDIX D

ELECTROCARDIOGRAPH VARIABLES

COLUMN(S)	DESCRIPTION
5-6	"37" (Card Number)
7-10	I.D. Number
11-16	Date
17-20	Time
21	(Before Exercise 1 ((After Exercise 2
22-24	Rate Atrial
25-27	Rate Ventricular
28-29	Mechanism (Rhythm)
	01 Sinus Rhythm (normal)
	02 Supraventricular Tachycardia
	03 (Atrial Premature Contractions ((Nodal Premature Contractions
	04 Atrial Flutter
	05 Atrial Fibrillation
	06 Ventricular Premature Contractions
	07 Ventricular Tachycardia
	08 Idioventricular Rhythm
	09 Sinus Arrhythmias
	10 Nodal Pacemaker
	11 Coronary Sinus
30-33	Axis Deviation $\pm$ XXX °
34-35	P-R Interval
	P-Waves Deflections
	Codes: 1=Normal, 2=Bifid, 3=Peaked, 4=Decreased, 5=Inverted, 6=Diphasic, 7=Widened

COLUMN(S)   DESCRIPTION

Leads

36   1

37   2

38   3

39   AVR

40   AVL

41   AVF

42 V_1

43 V_2

44 V_3

45 V_4

46 V_5

47 V_6

48-49   QRS Duration

QRS Deviation

Codes: 1=Progression Normal, 2=rR^1,
3=R/S ratio $\widetilde{=}$1, 4=Low Voltage,
5=small Q noted, 6=Inverted
7=R Progression Delayed

Leads

50   1

51   2

52   3

53   AVR

54   AVL

55   AVF

COLUMN(S)	DESCRIPTION
	......
	Leads (cont.)
56	V_1
57	V_2
58	V_3
59	V_4
60	V_5
61	V_6
62-63	T-Wave Duration
64	T-Wave Position
	Codes: 1=Upright, 2=Isoelectric, flat-low amplitude, 3=Inverted
	S-T Segment
	Codes: 1=Normal, Isoelectric, 2=Depressed, 3=Biphasic, 4=Coved, 5=Elevated
	Leads:
65	1
66	2
67	3
68	AVR
69	AVL
70	AVF
71	V_1
72	V_2
73	V_3
74	V_4
75	V_5
76	V_6

CARD 37 - ECG (Cont.)

<u>COLUMN(S)</u>

77-78

<u>DESCRIPTION</u>

Conclusion

<u>Codes</u>: 1=Normal

2=Enlargement Atrial RT

3=Enlargement Atrial LT

4=Enlargement Ventricle RT

5=Enlargement Ventricle LT

6=Infarction

7=Injury

8=Drug Effect

9=Pulmonary Disease

10=Non-Specific

11=Rhythm Disturbance

12=Premature Junctional Systole

13=Low voltage to the limb leads

14=BiVentricular Hypertrophy

15=Improper Lead Position

16=Inferior Subendocardial Ischemia

APPENDIX E

BLOOD SAMPLE FORM

HEMATOLOGY

HEMATOLOGY	REQUESTED BY:		DATE	

☐ CBC ☐ ADM ☐ Hgb ☐ Hct ☐ RBC ☐ WBC ☐ DIFF.

CURRENT DIAGNOSIS:

DATE

TIME SPEC. OBTAINED

	TEST	NORMALS M	F
	WBC X10³	4.8 10.8	4.8 10.8
IF 99.9 RE-DILUTE			
	RBC X10²	4.6 6.2	4.2 5.4
	Hgb gm	14 18	12 16
	Hct %	42 52	37 47
	MCV μ³	82 TO 99	
	MCH μμg	27 TO 32	
	MCHC %	32 TO 36	

REMARKS

VOUCHER # 5

DIFFERENTIAL: PLATELETS:

NEUTROPHILES	%	NORMAL
SEGMENTED	%	INCREASED
BAND FORMS	%	DECREASED
METAMYELOCYTES	%	**RBC**
MYELOCYTES	%	NORMAL
EOSINOPHILES	%	ANISOCYTOSIS
BASOPHILES	%	HYPOCHROMIA
LYMPHOCYTES	%	POIKILOCYTOSIS
MONOCYTES	%	POLYCHROMASIA

REMARKS:

ST. FRANCIS HOSPITAL
LYNWOOD, CALIFORNIA

R. F. HUFNER, M.D
J. N. CARBERRY, M.D
DIRECTORS OF LABORATORY

APPENDIX F

DAILY SYMPTOM RECORD

DAILY SYMPTOM RECORD

Mr.
Mrs. _____
Miss   Last   First

Identification No. _____

DATE OF TEST:

Mo. [   ]   Day [   ]

Hr. [   ]   Min. [   ]

ALL PANELISTS

1. Do you have any discomfort now?

		Yes	No
	Eyes?	☐	☐
	Throat?	☐	☐
	Chest?	☐	☐
	Headache?	☐	☐
	Nausea?	☐	☐
	Other?	_____	

2. Have you had a headache earlier today?   Yes ☐   No ☐

3. Have you felt any unusual shortness of breath today?   Yes ☐   No ☐

4. Have you been coughing at all today?   Yes ☐   No ☐

     4a. IF "Yes" TO 4, ASK: Has your coughing brought up any phlegm from your chest?   Yes ☐   No ☐   NA ☐

5. Did you smoke cigarettes today?   Yes ☐   No ☐

     5a. IF "Yes" TO 5, ASK: How many?   _____ cigarettes

6. Do you have a bad cold today?   Yes ☐   No ☐

7. Have you taken any medicine today?   _____

ASTHMA AND OUTDOOR WORKER PANELS   Temp. _____

_____   _____   _____   _____

$FEV_{1.0}$ $FEV_{1.0}$ $FEV_{1.0}$ MAX. $FEV_{1.0}$

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ATHLETE PANEL - (After their exertion)

Time Trial: Distance _____   Time _____
                                                 minutes, seconds

Time of Day: Race ended _____   Final tests start _____
                          hour, minute   hour, minute

8.   Do you have any discomfort now?

                    Eyes?   Yes ☐   No ☐

                    Throat?   Yes ☐   No ☐

                    Chest?   Yes ☐   No ☐

                    Headache?   Yes ☐   No ☐

                    Nausea?   Yes ☐   No ☐

                    Other?   _____

9.   Have you coughed since the race?   Yes ☐   No ☐

    9a.   IF "Yes" to 9, ASK: Did your coughing bring up any   Yes ☐   No ☐ NA ☐
           phlegm from your chest?

APPENDIX G

CLINICAL INTERVIEW QUESTIONNAIRE

CLINICAL INTERVIEW QUESTIONNAIRE

Mr.
Mrs.
Miss _____   Interviewer No. _____

Birthdate _____   I.D. No. _____
         Month   Day   Year

Age _____   Date of Test _____
                                 Month   Day   Year

Sex   ☐ F   ☐ M

Height _____ ft. _____ inches

PREAMBLE: I am going to ask you some questions about your chest. Please
answer "Yes" or "No" whenever possible.

1. Do you usually cough first thing in the morning in winter?
   (COUNT TWO OR MORE COUGHS UPON ARISING, OR WHEN
   SUBJECT FIRST GOES OUT OF DOORS, OR WHEN SUBJECT
   SMOKES THE FIRST CIGARETTE OF THE DAY IF HE/SHE
   IS A SMOKER. DO NOT COUNT CLEARING OF THROAT.)   Yes ☐ No ☐

(IF "Yes" TO QUESTION 1, PLEASE ASK QUESTION 2.)

2. Do you cough like this on most days (or nights) for as much as three
   months each year?   Yes ☐ No ☐ NA ☐

3. Do you usually cough during the day or night in winter? (DO NOT
   COUNT AN OCCASIONAL COUGH.)   Yes ☐ No ☐

(IF "Yes" TO QUESTION 3, PLEASE ASK QUESTION 4.)

4. Do you cough like this on most days (or nights) for as much as three
   months each year?   Yes ☐ No ☐ NA ☐

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5. Do you usually bring up phlegm (thick fluid) from your chest first thing in the morning in winter? (COUNT PHLEGM WHETHER SWALLOWED OR EXPELLED, UPON ARISING, OR WHEN SUBJECT FIRST GOES OUT OF DOORS, OR WHEN SUBJECT SMOKES THE FIRST CIGARETTE OF THE DAY IF HE/SHE IS A SMOKER. DO NOT COUNT PHLEGM FROM THE NOSE.)

Yes ☐   No ☐

(IF "Yes" TO QUESTION 5, PLEASE ASK QUESTION 6.)

6. Do you bring up phlegm like this on most days (or nights) for as much as three months each year?

Yes ☐   No ☐   NA ☐

7. Do you usually bring up phlegm from your chest during the day or night in winter?

Yes ☐   No ☐

(IF "Yes" TO QUESTION 7, PLEASE ASK QUESTION 8.)

8. Do you bring up phlegm like this on most days or nights for as much as three months each year?

Yes ☐   No ☐   NA ☐

9. In the past three years, have you had a period of cough and phlegm lasting for three weeks or more? (ALL PERSONS SHOULD ANSWER THIS QUESTION. IF SUBJECT USUALLY HAS COUGH OR PHLEGM, THE QUESTION REFERS TO PERIODS OF MORE THAN USUAL COUGH OR PHLEGM.)

No ☐

Yes, 1 period ☐

Yes, 2 or more periods ☐

10. Are you troubled by shortness of breath when hurrying on level ground or walking up a slight hill?

Yes ☐   No ☐

11. Do you get short of breath walking with other people of your own age on level ground?

Yes ☐   No ☐

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12. Does the weather affect your chest or your breathing? If yes, specify how and what type of weather, e.g., fog, damp, heat, cold.

No ☐

_____

Yes, chest ☐

Yes, breathing ☐

13. Do you usually have a stuffy nose or runny nose in the winter?

Yes No ☐ ☐

14. Do you have this in summer?

Yes No ☐ ☐

15. During the past three years, have you had any chest illness which has kept you from your usual activities for as much as a week?

Yes No ☐ ☐

(IF "No" TO QUESTION 15, ASK QUESTION 18.)
(IF "Yes" TO QUESTION 15, ASK QUESTION 16.)

16. Did you bring up more phlegm than usual in any of these illnesses?

Yes No NA ☐ ☐ ☐

(IF "No" TO QUESTION 15, ASK QUESTION 18.)
(IF "Yes" TO QUESTION 15, ASK QUESTION 17.)

17. How many illnesses like this have you had in the past three years?

1 illness ☐

2 or more illnesses ☐

NA ☐

Present and Past Illnesses

18. Do you now have any serious illness? If yes, specify._____

Yes No ☐ ☐

_____

19. Has a doctor ever told you that you have emphysema?

Yes No ☐ ☐

(IF "Yes" TO QUESTION 19, ASK QUESTION 20.)

20. Are you now taking medicine for this?

Yes No NA ☐ ☐ ☐

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21. Have you ever had <u>chronic bronchitis?</u>　　　　　　　　Yes　No
　　　　　　　　　　　　　　　　　　　　　　　　　　　　　☐　☐

(IF "Yes" TO QUESTION 21, ASK QUESTION 22.)
　　　　　　　　　　　　　　　　　　　　　　　　　　　Yes　No　NA
22. Has a doctor told you that you <u>now</u> have this?　　　☐　☐　☐

(IF "Yes" TO QUESTION 21, ASK QUESTION 23.)
　　　　　　　　　　　　　　　　　　　　　　　　　　　Yes　No　NA
23. Are you now taking medicine for this?　　　　　　　☐　☐　☐

　　　　　　　　　　　　　　　　　　　　　　　　　　　　Yes　No
24. Have you ever had <u>asthma</u> diagnosed by a doctor?　☐　☐

(IF "Yes" TO QUESTION 24, ASK QUESTION 25.)
　　　　　　　　　　　　　　　　　　　　　　　　　　　Yes　No　NA
25. Has your asthma been active in the past two years?　☐　☐　☐

　　　　　　　　　　　　　　　　　　　　　　　　　　　　Yes　No
26. Did you ever have <u>hay fever?</u>　　　　　　　　　　☐　☐

(IF "Yes" TO QUESTION 26, ASK QUESTION 27.)
　　　　　　　　　　　　　　　　　　　　　　　　　　　Yes　No　NA
27. Has your hay fever been active in the past two years?　☐　☐　☐

　　　　　　　　　　　　　　　　　　　　　　　　　　　　Yes　No
28. Did you ever have <u>chronic sinusitis?</u>　　　　　　　☐　☐

(IF "Yes" TO QUESTION 28, ASK QUESTION 29.)
　　　　　　　　　　　　　　　　　　　　　　　　　　　Yes　No　NA
29. Has your chronic sinusitis been active during the past two years?　☐　☐　☐

　　　　　　　　　　　　　　　　　　　　　　　　　　　　Yes　No
30. Did you ever have any <u>allergies?</u>　　　　　　　　　☐　☐

(IF "Yes" TO QUESTION 30, ASK QUESTION 31.)
　　　　　　　　　　　　　　　　　　　　　　　　　　　Yes　No　NA
31. Has your allergy been active during the past two years?　☐　☐　☐

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32. Have you ever had treatment for tuberculosis or any <u>other chronic</u> lung condition?
(IF "Yes," NOTE CONDITION:)_____

Yes No TB
☐ ☐ ☐

<u>Smoking Habits</u>

33. Have you ever smoked as many as five packs of cigarettes, that is, as many as 100 cigarettes, during your entire life?

Yes No
☐ ☐

34. Do you now smoke cigarettes?

Yes No
☐ ☐

35. If you are a current or an ex-cigarette smoker, how many cigarettes do (did) you smoke per day?

Less than 1/2 pack per day (1-5 cigarettes per day) ☐

About 1/2 pack per day (6-14 cigarettes per day) ☐

About 1 pack per day (15-25 cigarettes per day) ☐

About 1-1/2 packs per day (26-35 cigarettes per day) ☐

About 2 packs per day (35 or more cigarettes per day) ☐

36. If you are a current or an ex-cigarette smoker, how old were you when you first started smoking?

☐☐ Years

37. If you are an ex-cigarette smoker, how old were you when you last gave up smoking?

☐☐ Years

38. Do you smoke a pipe?

Yes No Exsm.
☐ ☐ ☐

Date stopped:_____
If yes, how many pipefuls per day?_____

39. Do you smoke cigars?

Yes No Exsm.
☐ ☐ ☐

Date stopped:_____
If yes, how many per day?_____

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General Questions

40. At your job are you now or have you been frequently exposed to
    irritating smoke, dust, or fumes?
    Yes ☐ No ☐

(IF "Yes" TO QUESTION 40, ASK QUESTIONS 41, 42, AND 43.)

41. What kind of irritant were you exposed to? (For example: coal dust,
    cutting oils, asbestos, mine dust, smelter fumes, raw cotton dust,
    foundry dust) Specify:_____

    _____

    _____

42. How long were you exposed?
    NA ☐

    Less than 1 year ☐

    1 to 5 years ☐

    6 to 10 years ☐

    More than 10 years ☐

43. Have you been exposed to irritating smoke, dust, or fumes at your job
    during the past year?
    Yes ☐ No ☐ NA ☐

44. Where were you born?_____
    City   State   Country

45. How long have you lived at your present address?
    ☐☐ Years

46. How long have you lived in the Los Angeles area?
    ☐☐ Years

47. Have you ever changed occupations because of a breathing (lung)
    problem?
    Yes ☐ No ☐

48. Have you ever changed residence location because of a breathing
    (lung) problem?
    Yes ☐ No ☐

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49. Have any of your "blood" relatives ever had persistent asthma, bronchitis, or emphysema?

Yes No
☐ ☐

50. How many rooms are there in your living quarters? (Do not count bathrooms, porches, balconies, foyers, halls, or halfrooms.)

☐☐ Rooms

51. How many people live in your household?

☐☐ People

52. What kind of stove is used for cooking in your home?

Gas ☐

Electric ☐

Other ☐

53. What educational level have you and/or the head of your household completed?

	Respondent	Head of Household (if applicable)
Elementary school	☐	☐
Part of high school	☐	☐
High school graduate	☐	☐
Part of college	☐	☐
College graduate	☐	☐
Graduate school, including advanced and professional degrees	☐	☐
Trade, technical, or business school beyond high school	☐	☐

54. What is your current marital status?

Single ☐ Separated or divorced ☐ Other (specify) ☐

Married ☐ Widow or widower ☐ _____

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55. Are you now pregnant? (We cannot X-ray pregnant women on the   Yes   No   NA
      Breathmobile.)   ☐   ☐   ☐

(INTERVIEWER: GIVE YOUR BEST ESTIMATE OF THE SUBJECT'S
RACE/ETHNIC GROUP, BUT DO NOT QUESTION HIM DIRECTLY.)

                                  American Indian   ☐

                                  Black/Afro American   ☐

                                  Spanish/Mexican/Puerto Rican-American   ☐

                                  Oriental-American   ☐

                                  White/Caucasian-American   ☐

                                  Other_____   ☐
                                        (SPECIFY, INCLUDING MIXED)

Thank you for your cooperation.

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APPENDIX H

AEROMETRIC DATA BASE

AEROMETRIC DATA BASE

The original study protocol required that aerometric data from the EPA air monitoring stations at Glendora (0841) and Covina (0842) be used in the analysis of the health information. During the study period, many of these data were missing because of various operational difficulties. This section of the report describes the content of the EPA data base and justifies the steps that were taken to fill gaps in the base.

OXIDANT

If oxidant values are tabulated for all study days for which data are available from both EPA air monitoring stations 0841 and 0842 (with no more than four hourly averages missing), it is immediately apparent (see Table H-1) that the two stations did not always track each other. On some days, for example 257, 278, 283, and 288, the agreement was excellent. On many days (303 through 311) the oxidant values were so low that they did not constitute a good test for agreement between the two stations. On still other days (253, 255, 259, 273, 274, and 275) the recorded oxidant values were different at the two stations with lower values occurring at 0842.

It is helpful to know whether these differences represent genuine area differences in oxidant levels or merely a local distrubance or instrument malfunction at one of the monitoring sites. A comparison of EPA air monitoring station readings with those from nearby monitoring stations operated by the California Air Resources Board (ARB) at Temple City and the Los Angeles County Air Pollution Control District (APCD) at Azusa, help to clarify the situation. Data from all four stations are summarized in Table H-2 and relative locations of the stations are shown in Figure H-1. The Azusa and Glendora (0841) stations are both located in the foothills about four miles apart and, as expected, tend to give similar oxidant values. Readings at Glendora are slightly higher than those at Azusa. Readings at Covina (0842) tend to be considerably different from those at Azusa and Glendora, and on days 253, 255, and 259 the Temple City and Covina readings are similar. However, on days 273, 274, and 275 the oxidant levels at Covina were lower than those at any of the other stations which suggests a local disturbance or instrument malfunction. In summary, there appear to be

TABLE H-1. OXIDANT VALUES (PPM) FOR EPA AIR MONITORING STATIONS 0841 AND 0842

PDT	253 41*	253 42**	255 41*	255 42**	257 41*	257 42**	259 41*	259 42**	273 41*	273 42**	274 41*	274 42**	275 41*	275 42**	278 41*	278 42**	283 41*	283 42**	288 41*	288 42**
0700	.00	--	.01	--	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.03	--
0800	.02	--	.02	--	.02	.01	.04	.00	.00	.00	.02	.00	.00	.00	.00	.00	.02	.00	.03	--
0900	.07	.03	.04	.03	.04	---	.06	.04	.01	.00	.03	.01	.00	.00	.03	.02	.03	.00	.03	--
1000	.12	.10	.07	.06	.06	.04	.09	.07	.07	--	.06	.03	.02	.00	.04	.04	.04	.05	.05	.05
1100	.19	.21	.13	.09	.08	.07	.11	--	.09	--	.10	.05	.04	.02	.07	.06	.07	.07	.06	.07
1200	.26	.31	--	.15	.11	--	.19	.28	.19	.18	.14	.08	.09	.05	.08	.08	.09	.11	.07	.08
1300	.36	.37	.21	.18	.16	.17	.29	.26	.27	--	.20	.10	.13	.06	.11	--	.12	.13	.08	.09
1400	.40	.26	.22	.15	.21	.23	.22	.18	.39	.22	.23	.12	.11	.04	.13	---	.15	.17	.09	.10
1500	.35	.22	.18	.09	.24	.22	.19	--	.45	.22	.18	.09	.11	.05	.17	.16	.18	.19	.11	.11
1600	.31	.26	.14	.08	.26	.28	.15	.11	.36	.16	.12	.05	.09	--	.14	.13	.18	.17	.14	.14
1700	.26	.21	.11	.05	.20	.17	.09	.07	.22	.09	.09	.03	.04	--	.10	.08	.14	.12	.11	.08
1800	.14	.09	.06	.01	.12	.08	.04	.05	.11	.03	--	.00	--	.00	.06	.05	.09	.07	.07	.02
1900	.07	--	.01	.00	.05	.05	.01	.00	.05	.01	.00	.00	--	.00	.03	.01	.06	--	.09	.00

*41 = Station 0841 in Glendora (EPA)
**42 = Station 0842 in Covina (EPA)

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TABLE H-1 (continued). OXIDANT VALUES (PPM) FOR EPA AIR MONITORING STATIONS 0841 AND 0842

PDT	290 41*	290 42**	303 41*	303 42**	304 41*	304 42**	305 41*	305 42**	306 41*	306 42**	308 41*	308 42**	309 41*	309 42**	310 41*	310 42**	311 41*	311 42**
0700	.02	.00	.00	.00	.00	.00	.00	.00	.01	.00	.01	.00	.02	.00	.02	.00	.04	.00
0800	.02	.00	.01	.02	.01	.00	.00	.00	.02	.00	.01	.00	.03	.00	.03	.00	.02	.00
0900	.02	.00	.03	.03	.02	.03	.01	.02	.02	.02	.03	.01	.04	.01	.03	.02	.02	--
1000	.04	.03	.03	.04	.04	.04	.02	.03	.02	.02	.04	.03	.05	.03	.04	.04	.05	--
1100	.08	.05	.04	.05	.06	.05	.03	.03	.03	.02	.06	.07	.07	.08	.05	.05	.06	--
1200	.10	--	.05	.06	.06	.03	.03	.04	.03	.03	.08	.09	.08	.09	.05	--	.05	.06
1300	.16	--	.05	.07	.05	.01	.03	.04	.04	.04	.08	.10	.09	.11	.06	.07	.06	.07
1400	.18	.21	.06	.04	--	.01	.04	.03	.04	.04	.10	--	.08	.12	.07	.07	.06	.07
1500	.27	.23	.06	.04	.02	.00	.04	.02	.05	.03	.06	--	.08	.08	.07	.08	.08	.06
1600	.27	.23	.04	.02	--	.00	.02	.00	.05	.01	.02	.00	.06	.01	.07	.04	--	.00
1700	.20	.18	.03	.00	--	.00	.01	.00	.02	--	.00	--	.01	.00	.06	.00	.00	.00
1800	.10	.08	.00	.00	--	.00	.00	.00	.02	--	.00	.00	.03	.00	.06	.00	.01	.00
1900	--	.00	.00	.00	.00	.00	.00	.00	.00	--	.00	.00	.00	.00	.04	.00	.02	.00

*41 = Station 0841 in Glendora (EPA)
**42 = Station 0842 in Covina (EPA)

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TABLE H-2. COMPARISON OF OXIDANT VALUES FROM FOUR NEIGHBORING STATIONS

PDT	253				255				259				273				274				275			
	41	42	A*	T**	41	42	A*	T**	41	42	A*	T**	41	42	A*	T**	41	42	A*	T**	41	42	A*	T**
0700	.00	--	.01	.01	.01	--	.01	.01	.02	.00	.01	.02	.00	.00	.01	.02	.00	.00	.01	.01	.00	.00	.01	.01
0800	.02	--	.02	.03	.02	--	.02	.01	.04	.00	.01	.03	.00	.00	.01	.03	.02	.00	.01	.02	.00	.00	.01	.01
0900	.07	.03	.05	.06	.04	.03	.04	.02	.06	.04	.02	.04	.01	.00	.02	.04	.03	.01	.02	.03	.00	.00	--	--
1000	.12	.10	.09	.12	.07	.06	.06	.04	.09	.07	.05	.08	.07	--	.05	.08	.06	.03	.05	.05	.02	.00	.01	--
1100	.19	.21	.15	.22	.13	.09	.09	.07	.11	--	.10	.13	.09	--	.10	.13	.10	.05	.09	.09	.04	.02	.01	--
1200	.26	.31	.25	.31	--	.15	.14	.11	.10	.29	.19	.22	.19	.18	.19	.22	.14	.08	.15	.11	.09	.05	.08	.09
1300	.36	.37	.36	.37	.21	.18	.17	.14	.29	.26	.25	.38	.27	--	.25	.38	.20	.10	.18	.14	.13	.06	.11	.08
1400	.40	.26	.33	.26	.22	.15	.18	.13	.22	.18	.38	.36	.39	.22	.38	.36	.23	.12	.19	.14	.11	.04	.09	.06
1500	.35	.22	.30	.25	.18	.09	.13	.08	.19	--	.39	.29	.45	.22	.39	.29	.18	.09	.15	.11	.11	.05	.09	.05
1600	.31	.26	.27	.20	.14	.08	.09	.06	.15	.11	.29	.20	.36	.16	.29	.20	.12	.05	.10	.09	.09	--	.06	.03
1700	.26	.21	.20	.17	.11	.05	.06	.04	.09	.07	.19	.11	.22	.09	.19	.11	.09	.03	.08	.05	.04	--	.02	.02
1800	.14	.09	.14	.11	.06	.01	.04	.02	.05	.05	.10	.08	.11	.03	.10	.08	--	.00	.02	.02	--	.00	.01	.01
1900	.07	--	.08	.06	.01	.00	.01	.01	.01	.00	.06	.04	.05	.01	.06	.04	.00	.00	.01	.01	--	.00	.01	.01

*A = Azusa, L.A. Co. APCD values were multiplied by 1.28 to correct for different calibration procedure
**T = Temple City (California ARB)

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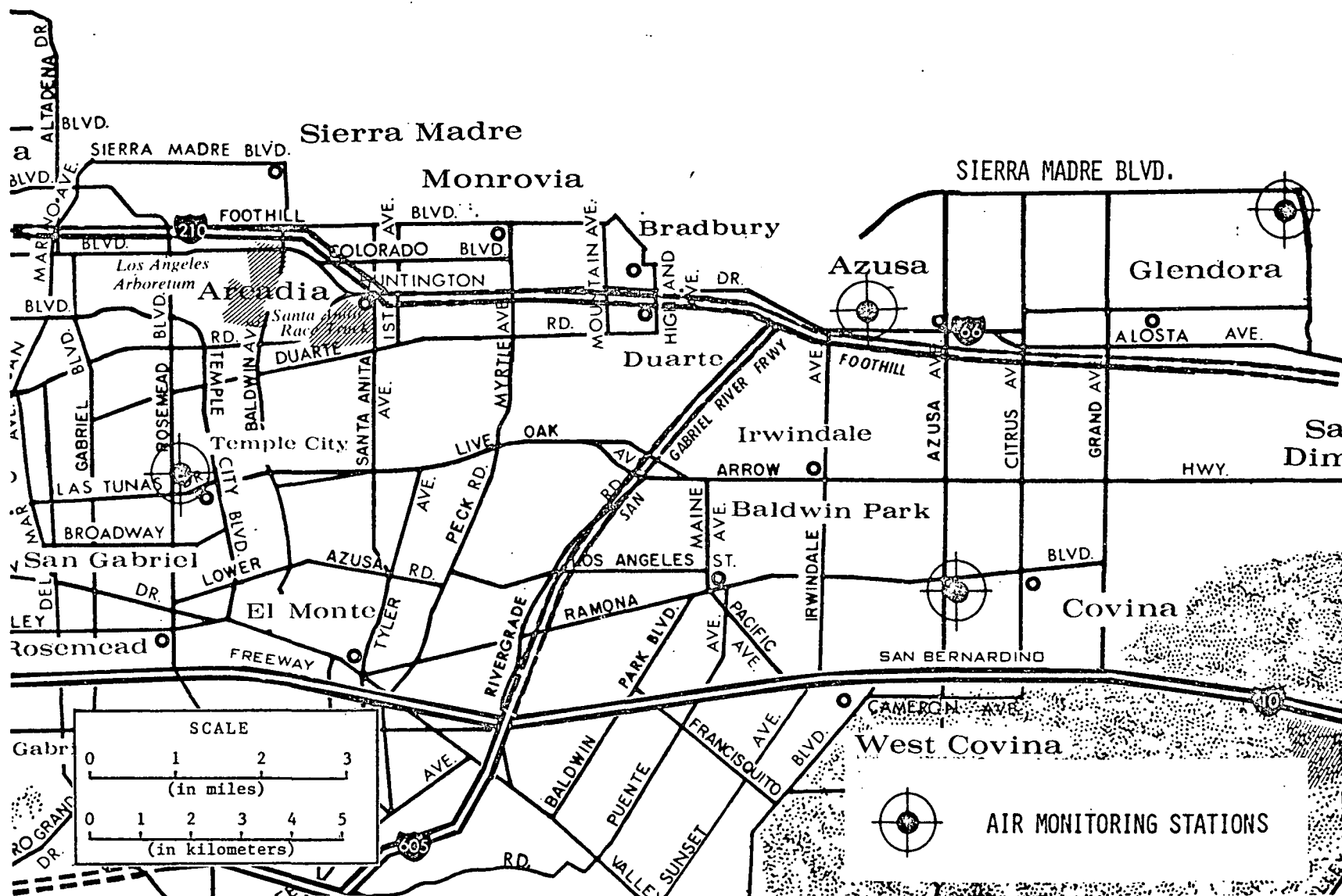
Figure H-1. Air Monitoring Station Locations

genuine area differences in oxidant levels between Glendora and Covina on some days with higher levels occurring at Glendora. In addition, there is evidence that suggests that some local effect at the Covina station caused unusually low oxidant values on days 273, 274, and 275.

If complete data were available from the Azusa, Covina, and Glendora stations, it would have been possible to prepare maps showing oxidant levels in all parts of the study area on each of the study days. Unfortunately, there were too many gaps in the Covina and Glendora data to make this possible. Instead, the oxidant values from the Azusa station were used in the data analysis for this study. The Azusa oxidant levels usually lie between the levels at the Glendora and Covina stations.

OXIDANT ADJUSTMENT FACTORS

Measurements of oxidant made by the Los Angeles County APCD, the California ARB, and the EPA are not directly comparable because of differences in calibration methods. This situation was recognized early in 1974, and an ad hoc committee* was appointed by the California ARB to determine which method was most accurate and to relate the correct method to prior measurements. The committee was also requested to recommend to the California ARB a reliable procedure for field monitoring of ozone. The final report of the committee was completed on February 20, 1975. Simultaneous measurements of oxidant were made by the three agencies on laboratory generated mixtures of ozone and air. Most of the discrepancies in oxidant readings were traced to differences in methods used for calibration of the measuring instruments. Questions were raised concerning the effects of absolute humidity on readings, and the California ARB carried out a special series of studies to investigate this effect. A draft report of the results was completed on May 14, 1975. The results show that the effects of humidity are measurable but small and do not override the differences caused by using different calibration methods.

The main purpose of the California ozone studies was to determine which method was most nearly correct and to evaluate the California episode criteria levels in view of the findings. The ad hoc committee found that the Federal Reference Method gave results that were approximately 24 percent too high while the

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*Dr. William B. DeMore, Chairman (Calif. Inst. of Technology, Jet Propulsion Laboratory); Mr. J. Cyril Romanovsky, Secretary (EPA); Mr. Milton Feldstein (Bay Area APCD); Mr. Walter J. Hamming (Los Angeles County APCD, retired); Dr. Peter K. Mueller (Environmental Research and Technology, Inc.).

Los Angeles County APCD method gave results that were 4 percent too low. Adjustment factors were proposed for converting oxidant levels from one agency's method to another's.

The California ozone studies provide information that can be used not only to adjust each ozone reading to the "correct" value but also to convert values measured by the Los Angeles County PACD to equivalent values measured by the EPA. The February 4, 1975, report finds that Los Angeles County APCD readings should be multiplied by 1.28 to give equivalent EPA readings, and the May 14, 1975, draft report indicates that this number should be 1.25. Other studies which are currently in progress may change the recommended adjustment factor again, but in view of all the other uncertainties associated with oxidant measurements, these changes are expected to be inconsequential. The factor of 1.25 was used in this report for converting Los Angeles County APCD oxidant values to equivalent EPA values.

OXIDES OF NITROGEN

The NO_2 values for all study days for which data are available for both EPA air monitoring stations (with no more than four hourly averages missing) are summarized in Table H-3.. Readings from the two stations sometimes agree closely (e.g., day 306) and sometimes differ considerable (e.g., day 309). In instances where the two stations differ, the higher NO_2 levels are registered at the Covina station. A comparison of the EPA air monitoring station readings with those from the Azusa and Temple City stations (Table H-4) shows that the Azusa and Temple City stations track reasonably well and give readings that are similar to those from the Covina station. On days when the Glendora readings differ, it appears that the Glendora station registered lower NO_2 values than are measured elsewhere in the study area.

For purposes of data analysis, the NO_2 values from the Azusa station were used. There were so many gaps in the EPA data that they could not be used as a consistent data base. The Azusa values are believed to be close to the EPA values for Covina and slightly higher than the EPA values for Glendora on days when the Covina and Glendora readings differ.

TABLE H-3. NO2 VALUES (PPM) FOR EPA AIR MONITORING STATIONS 0841 AND 0842

Day/Station PDT	280		290		304		305		306		308		309		310	
	41	42	41	42	41	42	41	42	41	42	41	42	41	42	41	42
0700	.06	.07	.02	.06	.02	.06	.04	.05	.00	.03	.02	.07	.03	.08	.01	.05
0800	.08	.09	.02	.06	.04	.07	.04	.04	.01	.03	.04	.09	.04	.11	.02	.06
0900	.09	.10	.03	.10	.05	.03	.03	.02	.02	.04	.04	.13	.04	.13	.02	.07
1000	.11	--	.07	.14	.03	.02	.03	.02	.02	.04	.06	.10	.05	.13	.01	.05
1100	.13	.16	.07	.06	.02	.02	.02	.02	.02	.04	.06	.06	.05	.07	.01	.02
1200	.13	.13	.04	--	.00	.04	.02	.04	.03	.04	.04	.05	.04	.09	.01	--
1300	.12	--	.06	--	.02	.05	.04	.05	.03	.05	.04	.08	.03	.08	.02	--
1400	.13	--	.10	.10	--	.05	.05	.04	.04	.06	.08	--	.04	.07	.02	.03
1500	.12	.12	.11	.08	.05	.05	.05	.05	.04	.06	.06	.07	.04	.05	.04	.05
1600	.11	.09	.12	.11	.06	.06	.06	.06	.05	.06	.07	--	.06	.14	.06	.10
1700	.09	.09	.14	.15	.07	.08	.06	.06	.07	.06	.07	.12	.10	.17	.06	.13
1800	.10	.10	.14	.20	.07	.08	.06	.06	.06	.07	.07	.10	.06	.15	.04	.13
1900	.10	.10	--	.17	.07	.08	.06	.05	.08	.07	.07	.10	.06	--	.05	.09

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TABLE H-4. NO2 VALUES (PPM) FOR NON-EPA STATIONS

PDT	280 A*	280 T**	290 A*	290 T*	304 A*	304 T**	305 A*	305 T**	306 A*	306 T**	308 A*	308 T**	309 A*	309 T**	310 A*	310 T**
0700	.06	.08	.02	.06	.01	.05	.05	.04	.01	.03	.04	.05	.06	.04	.02	.03
0800	.08	.11	.03	.09	.08	.05	.06	.06	.01	.04	.06	.05	.06	.05	.02	.05
0900	.09	.12	.03	.13	.05	.06	.06	.06	.04	.04	.09	.09	.09	.07	.02	.07
1000	.12	.16	.15	.15	.06	.05	--	.06	.04	.04	.12	.12	.10	.09	.05	.04
1100	.15	.15	.06	.12	.03	.02	--	.06	.04	.05	.09	.10	.11	.09	.04	.04
1200	.12	.15	.05	.11	.04	.04	.04	.06	.04	.05	.07	.08	.09	.10	.04	.04
1300	--	.16	--	.16	--	.07	--	.08	--	.05	--	.09	--	.11	--	.04
1400	.12	.17	.10	.16	.09	.08	.08	.07	.04	.06	--	.11	.08	.14	.04	.06
1500	.12	.13	.12	.18	.09	.07	.08	.06	.05	.08	.10	.08	.07	.10	.04	.07
1600	.10	.10	.11	.15	.08	.07	.08	.05	.08	.08	.09	.07	.07	.09	.07	.08
1700	.09	.10	.14	.21	.09	.08	.07	.05	.08	.08	.10	.10	.13	.10	.12	.11
1800	.09	.11	.17	.24	.10	.07	.08	.06	.09	.08	.13	.11	.18	.13	.15	.12
1900	.08	.11	.14	.27	.10	.07	.08	.05	.09	.06	.13	.11	.17	.13	.15	.12

*A = Azusa
**T = Temple City

APPENDIX I

PROPORTION OF ASTHMA PANEL REPORTING
DISCOMFORT SYMPTOMS AND WEIGHTED AVERAGES OF
AIR POLLUTION LEVELS CHARTED BY DAY NUMBER

ASTHMA PANEL DATA COLLECTION SCHEDULE

Discomfort symptoms and aerometric data were collected from members of the asthma panel on the dates shown below. This was during late summer and fall of 1974.

Day Number	Date		Sub-Panel	Day Number	Date		Sub-Panel
1	September	9	1	21	October	7	3
2		10	1	22		8	3
3		11	1	23		9	3
4		12	1	24		10	3
5		13	1	25		11	3
6		16	1	26		14	3
7		17	1	27		15	3
8		18	1	28		16	3
9		19	1	29		17	3
10		20	1	30		18	3
11		23	2	31		21	4
12		24	2	32		22	4
13		25	2	33		23	4
14		26	2	34		24	4
15		27	2	35		25	4
16		30	2	36		28	4
17	October	1	2	37		29	4
18		2	2	38		30	4
19		3	2	39		31	4
20		4	2	40	November	1	4

The portions of asthma panelists who reported discomfort symptoms are shown in Figures I-1 through I-9 for each of these 40 days.

In order to account for the effects on health associated with exposure to air pollutants and to humidity and temperature at the time the panelists were asked to complete Daily Symptom Records (shown in Appendix F), weighted averages had to be developed. In doing so the hour at which each panelist reported for testing was noted and the aerometric values for that hour were included in the weighted average for that day. The weighted averages of exposure are shown in Figures I-10 through I-15.
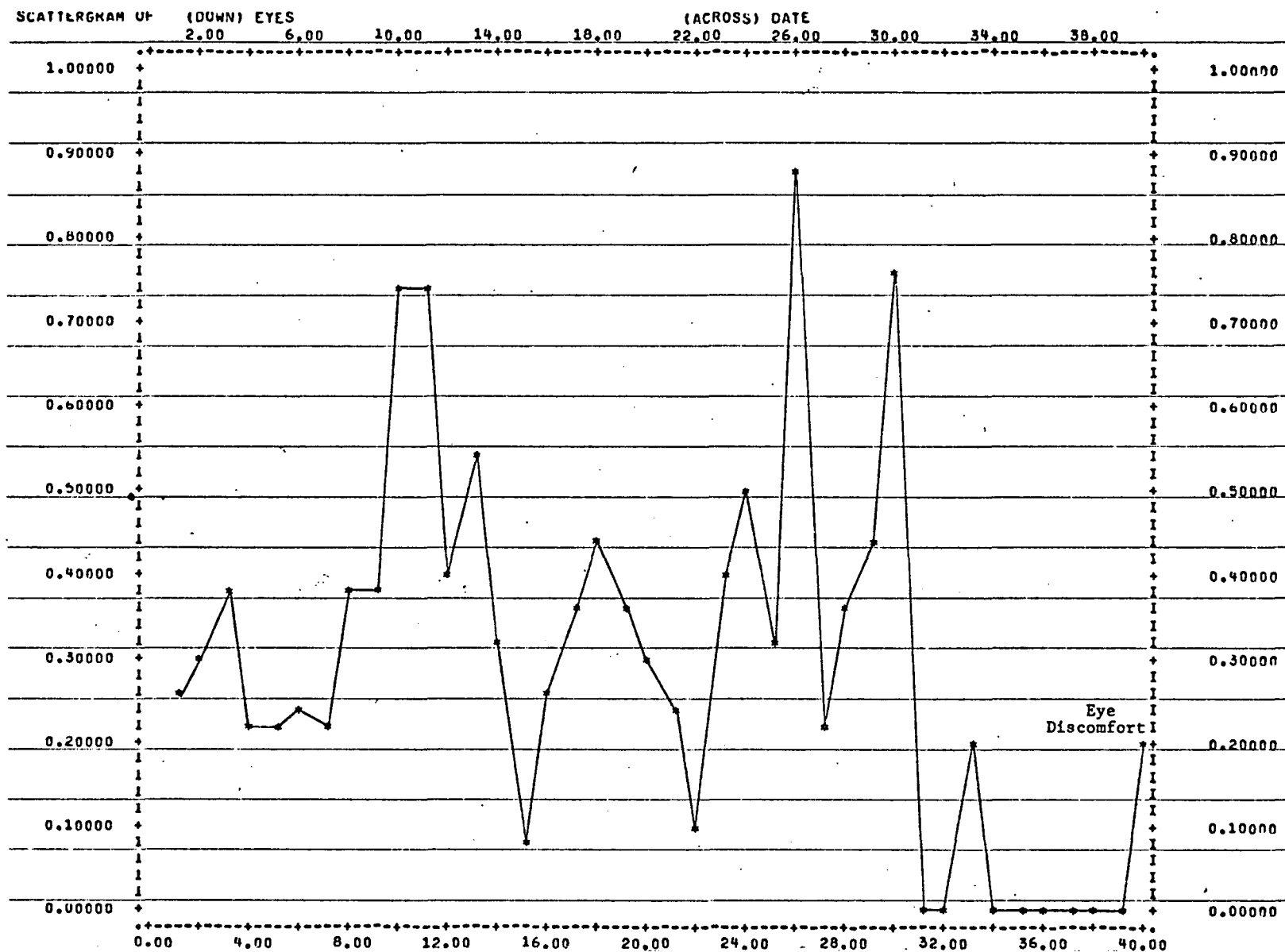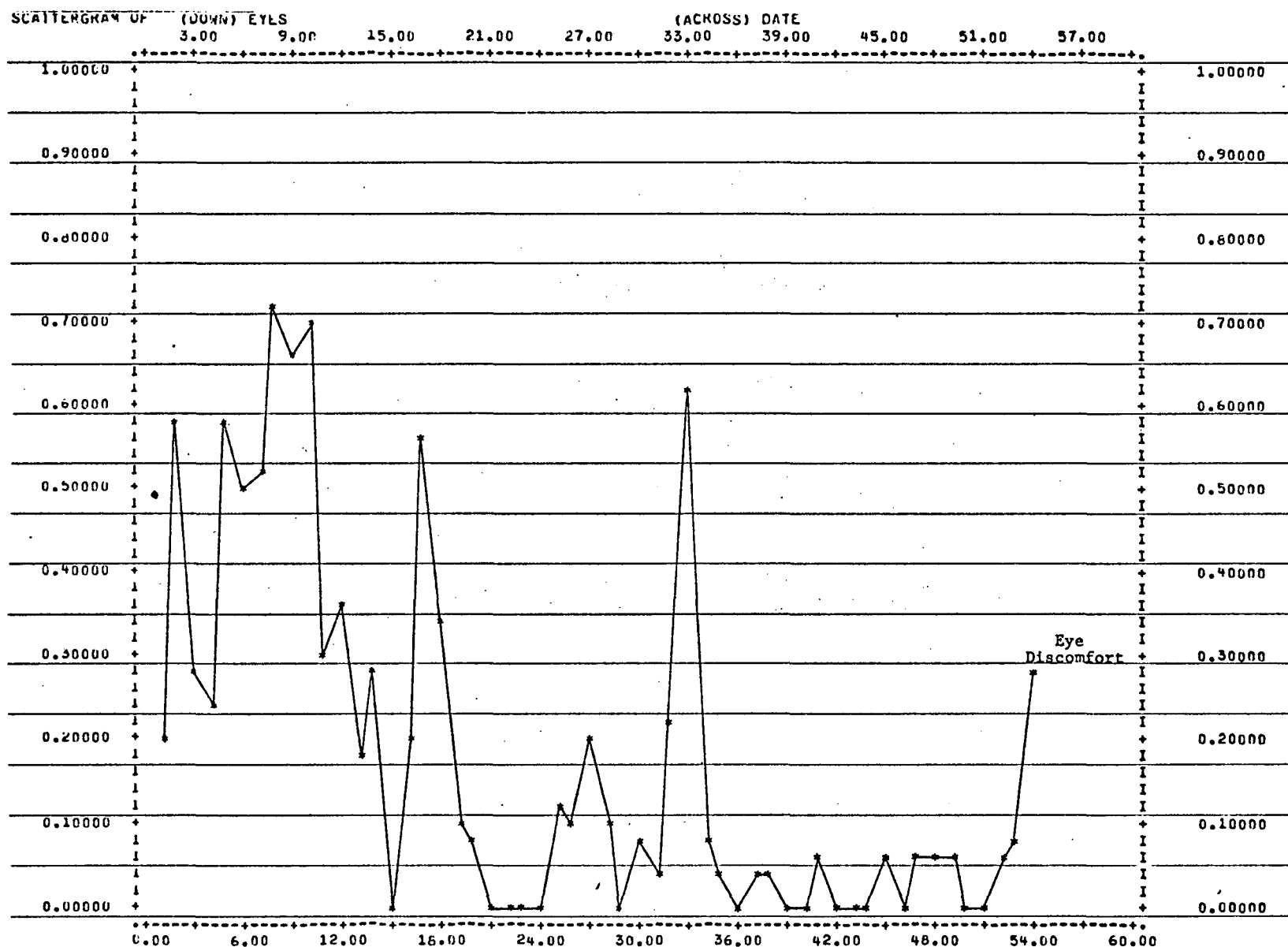
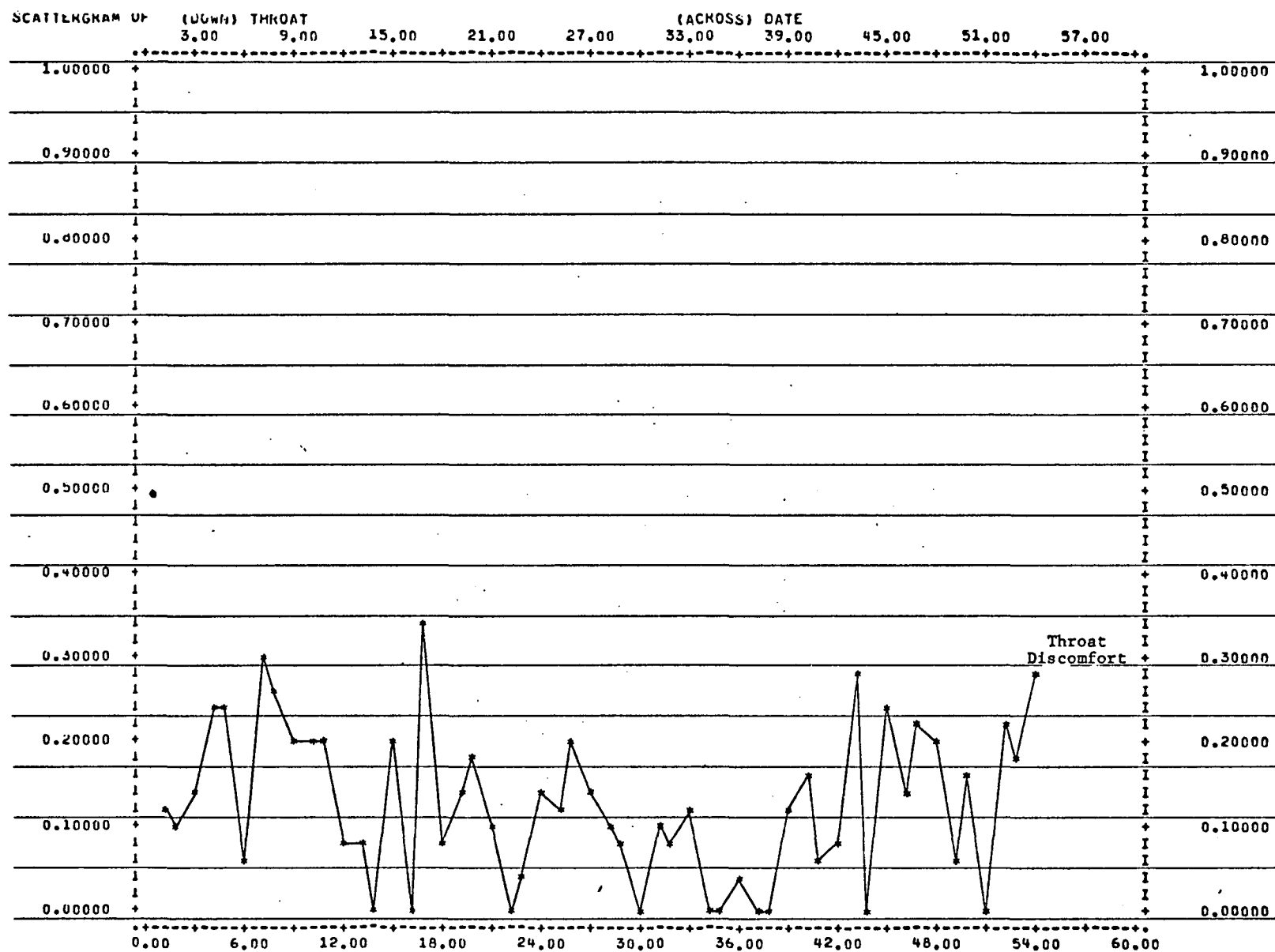Figure I-1. Proportion of asthma panel reporting eye discomfort by date.

SCATTERGRAM OF   (DOWN) THROAT   (ACROSS) DATE
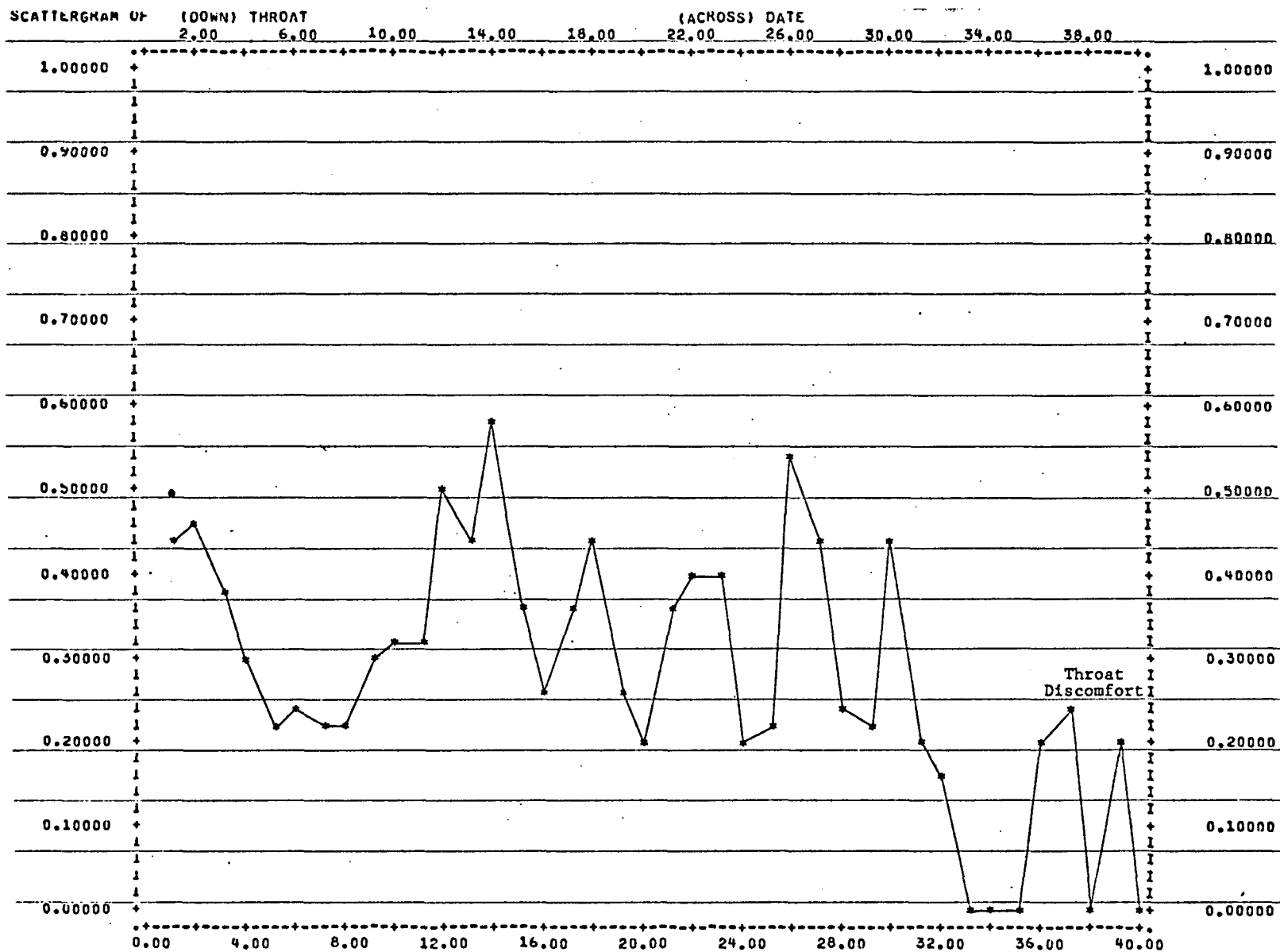
Figure I-2. Proportion of asthma panel reporting throat discomfort by date.
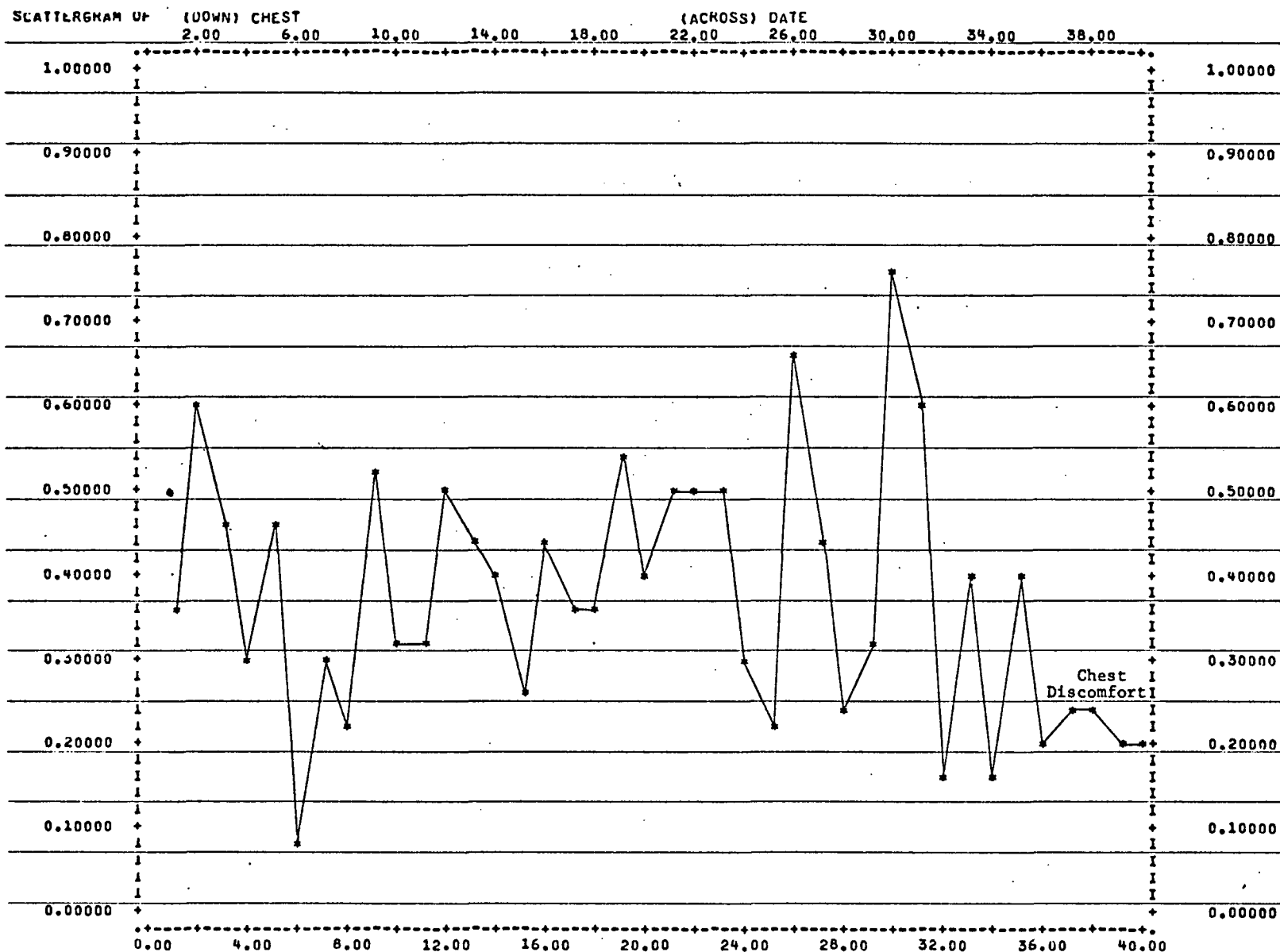
Figure I-3.   Proportion of asthma panel reporting chest discomfort by date.

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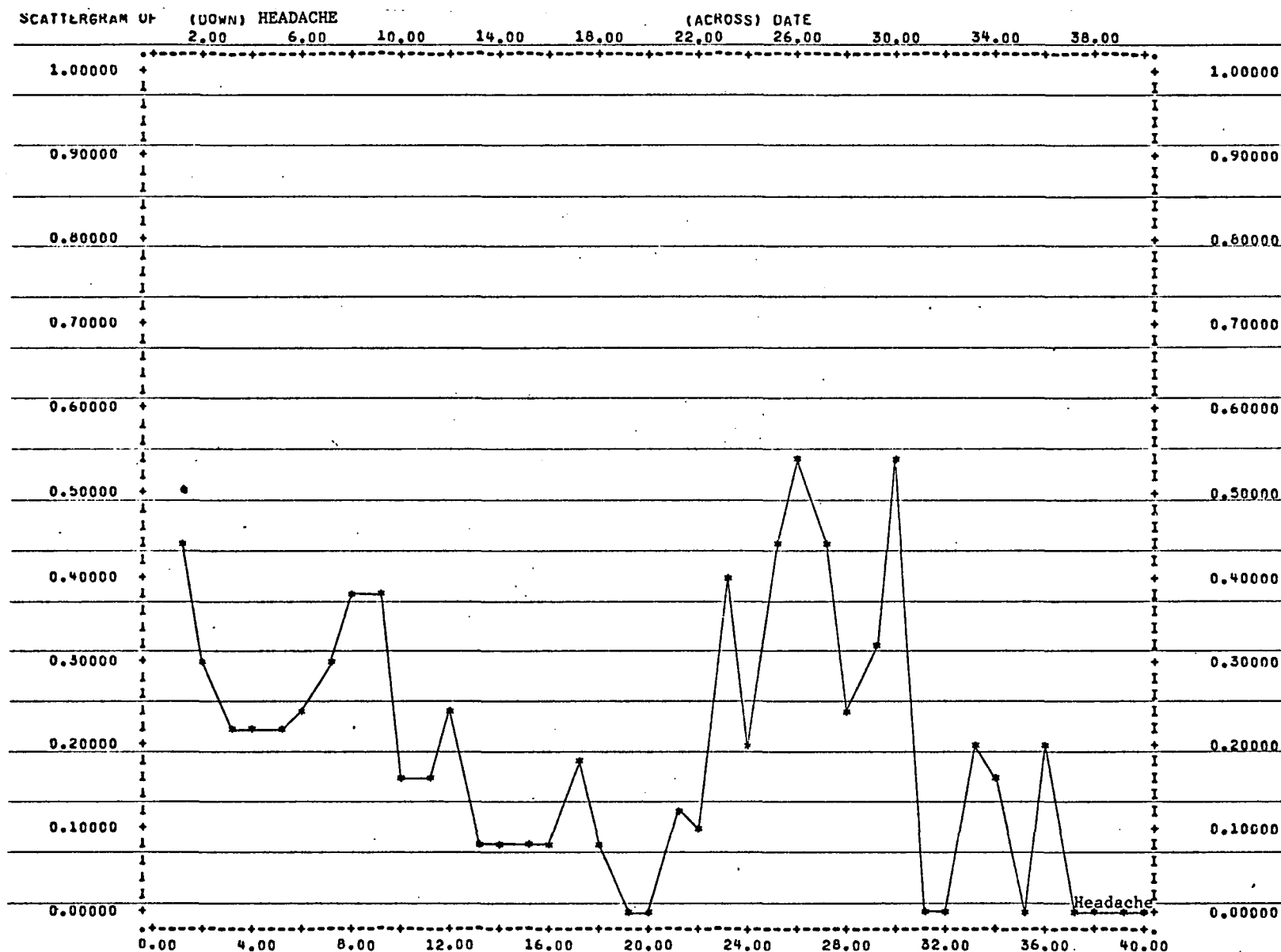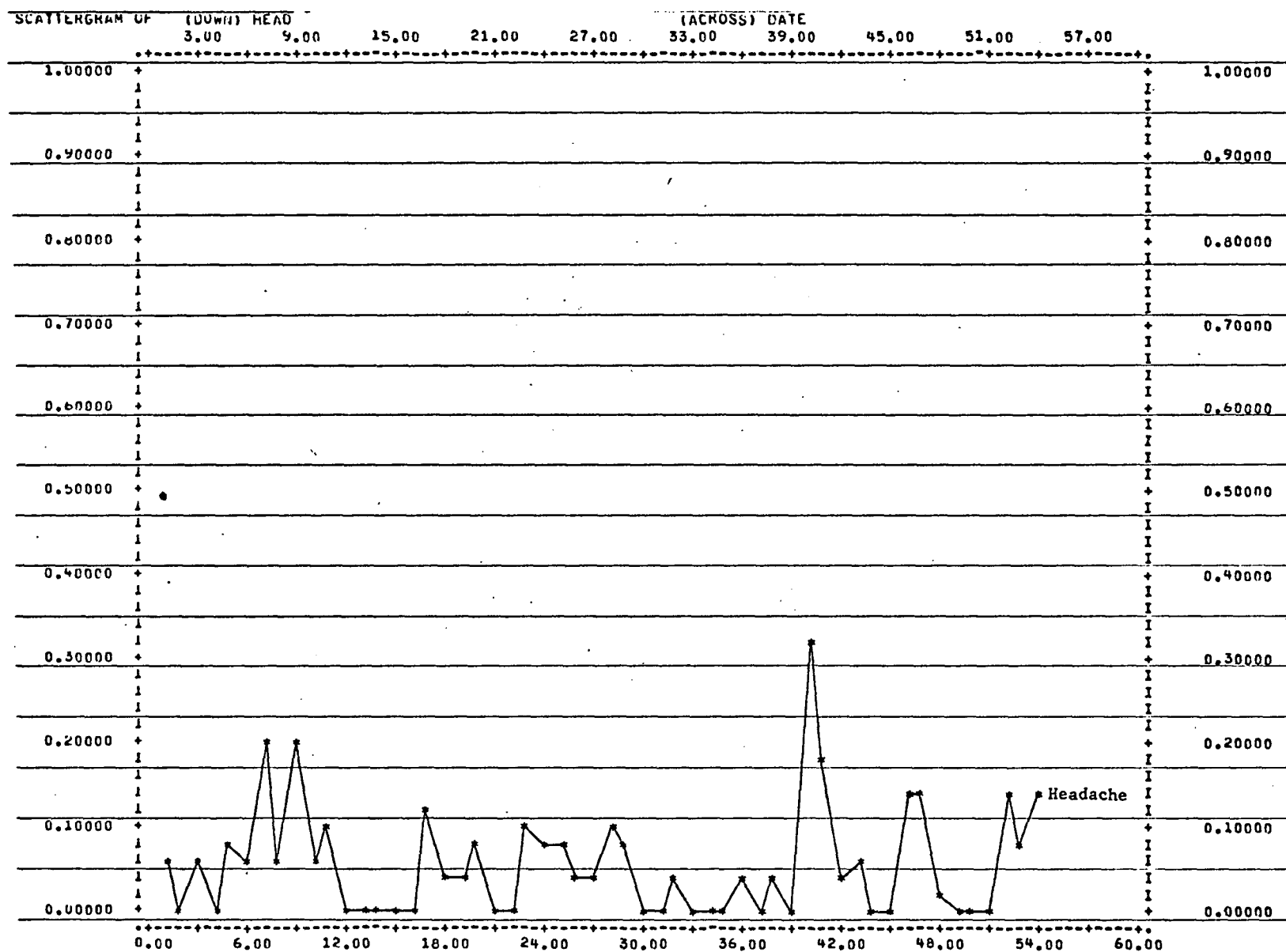
Figure I-4. Proportion of asthma panel reporting headache by date.
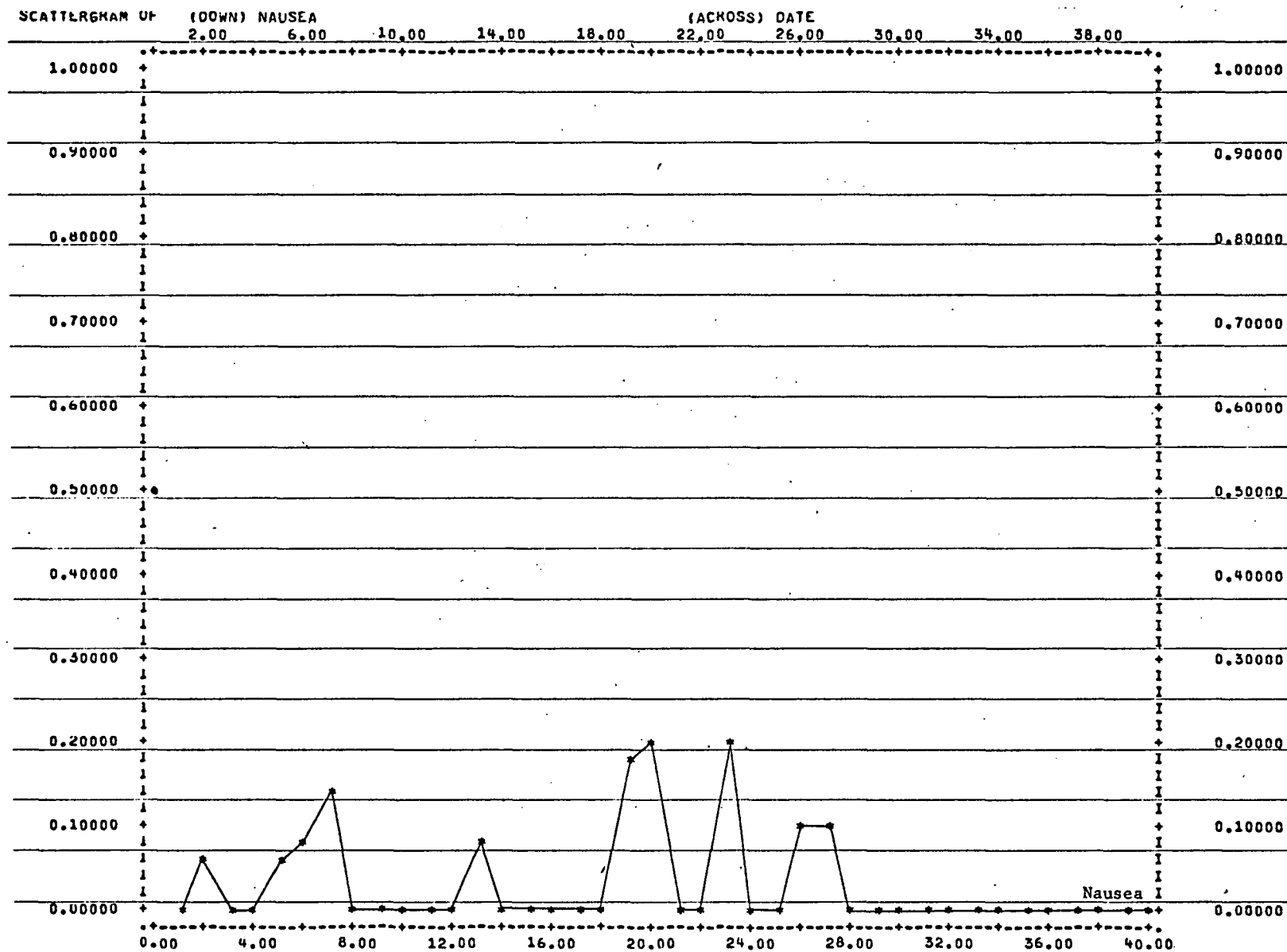
Figure I-5. Proportion of asthma panel reporting nausea by date.
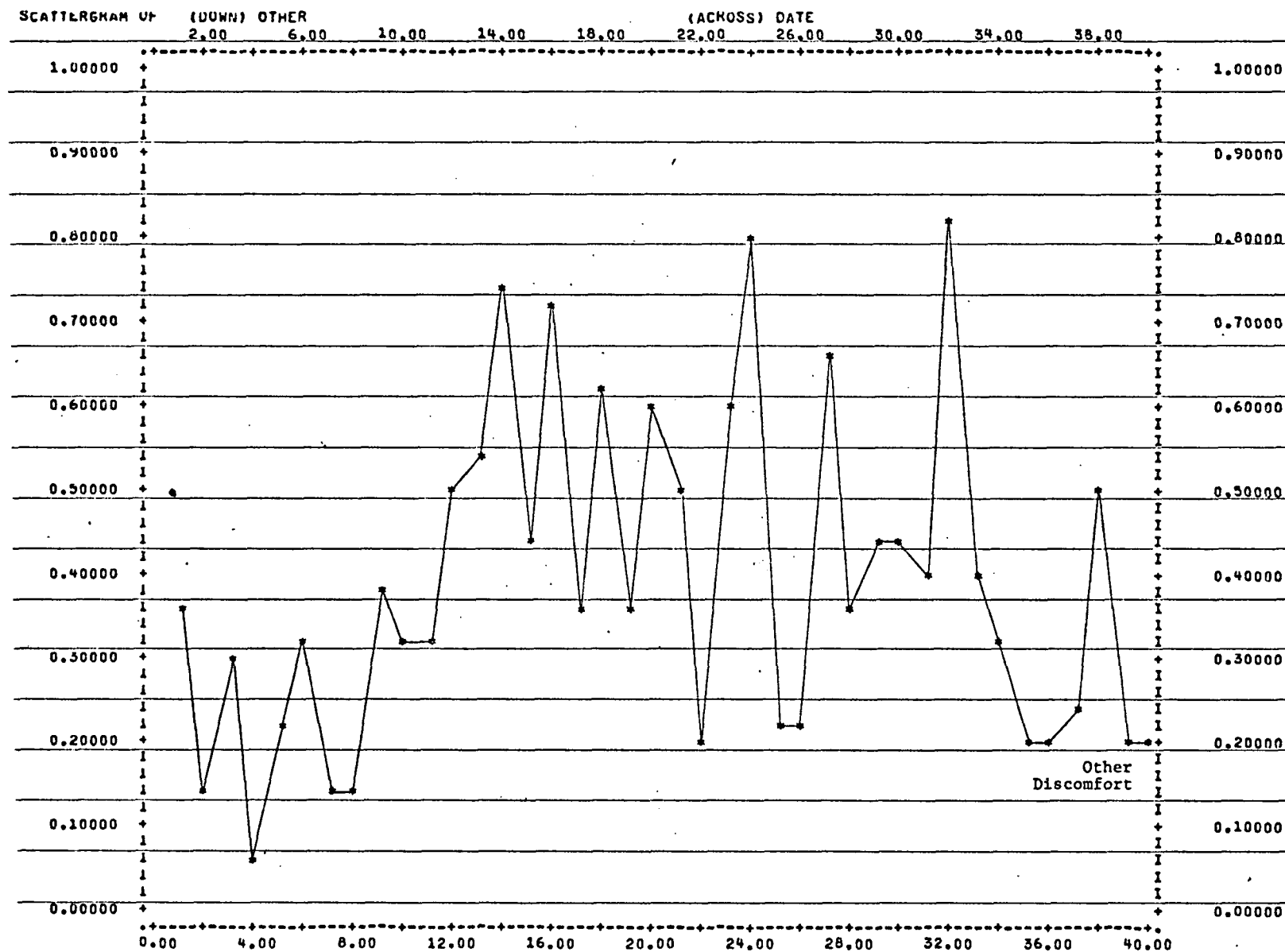
Figure I-6. Proportion of asthma panel reporting other discomfort by date.
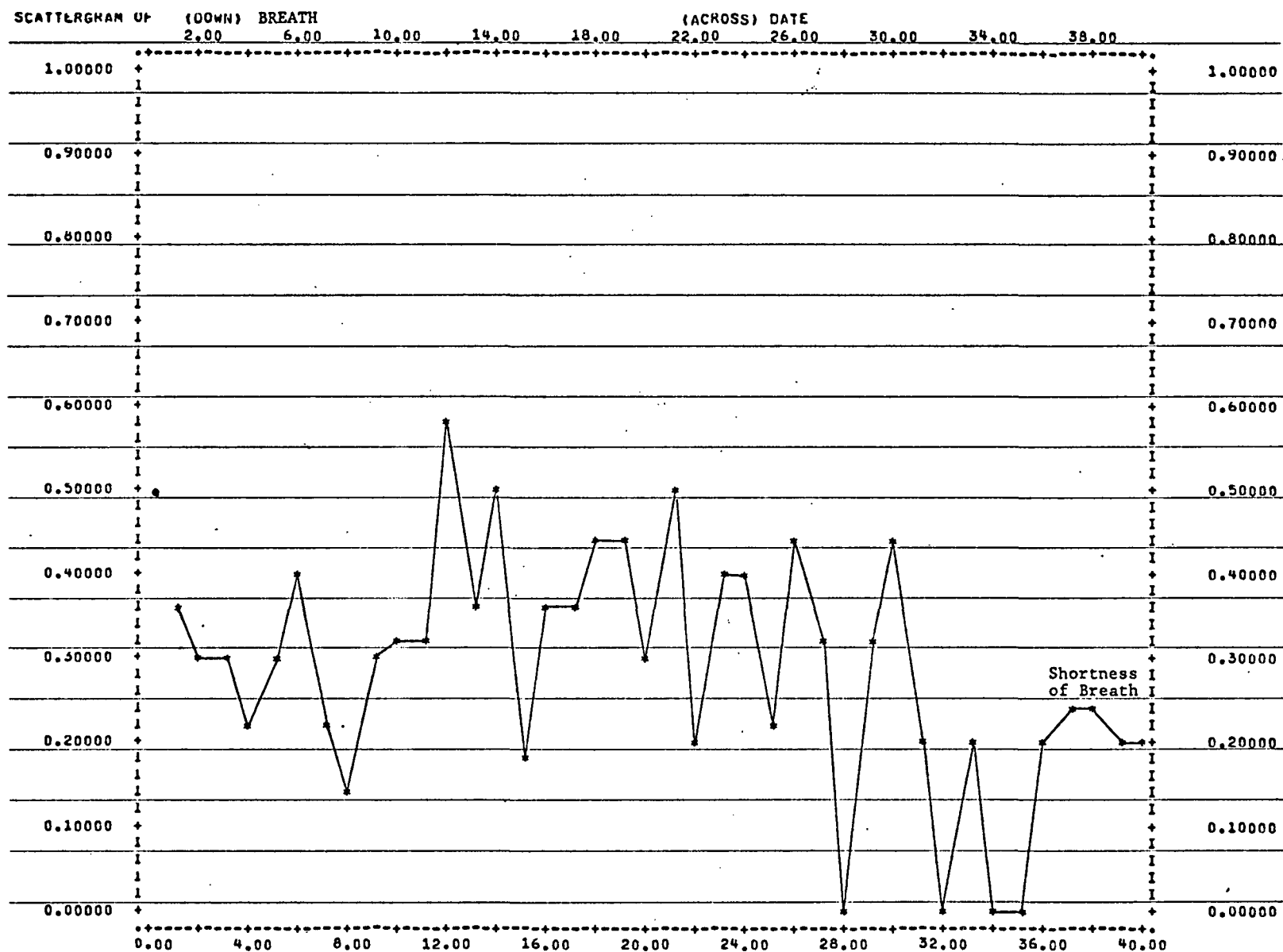
Figure I-7. Proportion of asthma panel reporting shortness of breath by date.
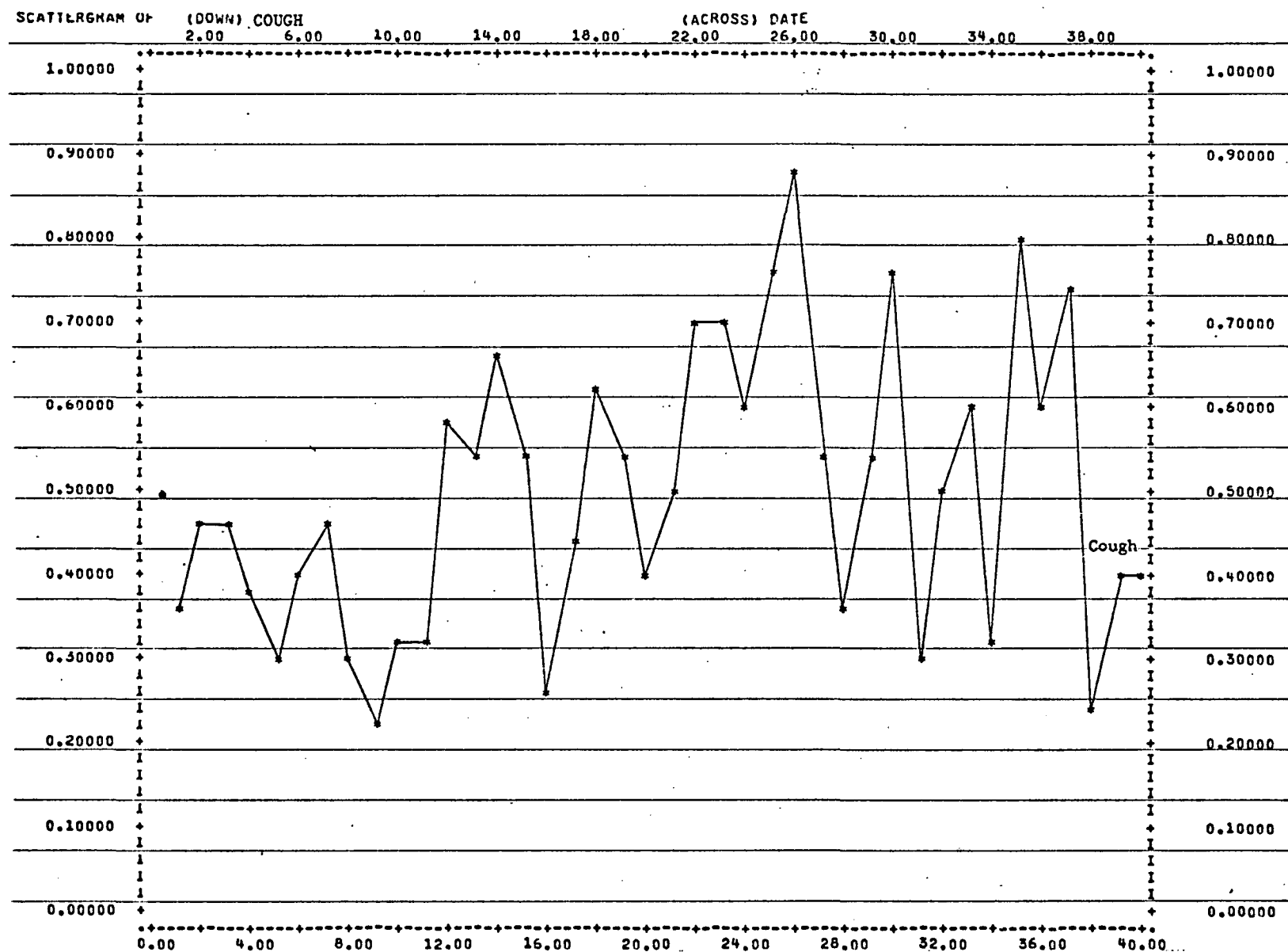
Figure I-8.   Proportion of asthma panel reporting cough by date.
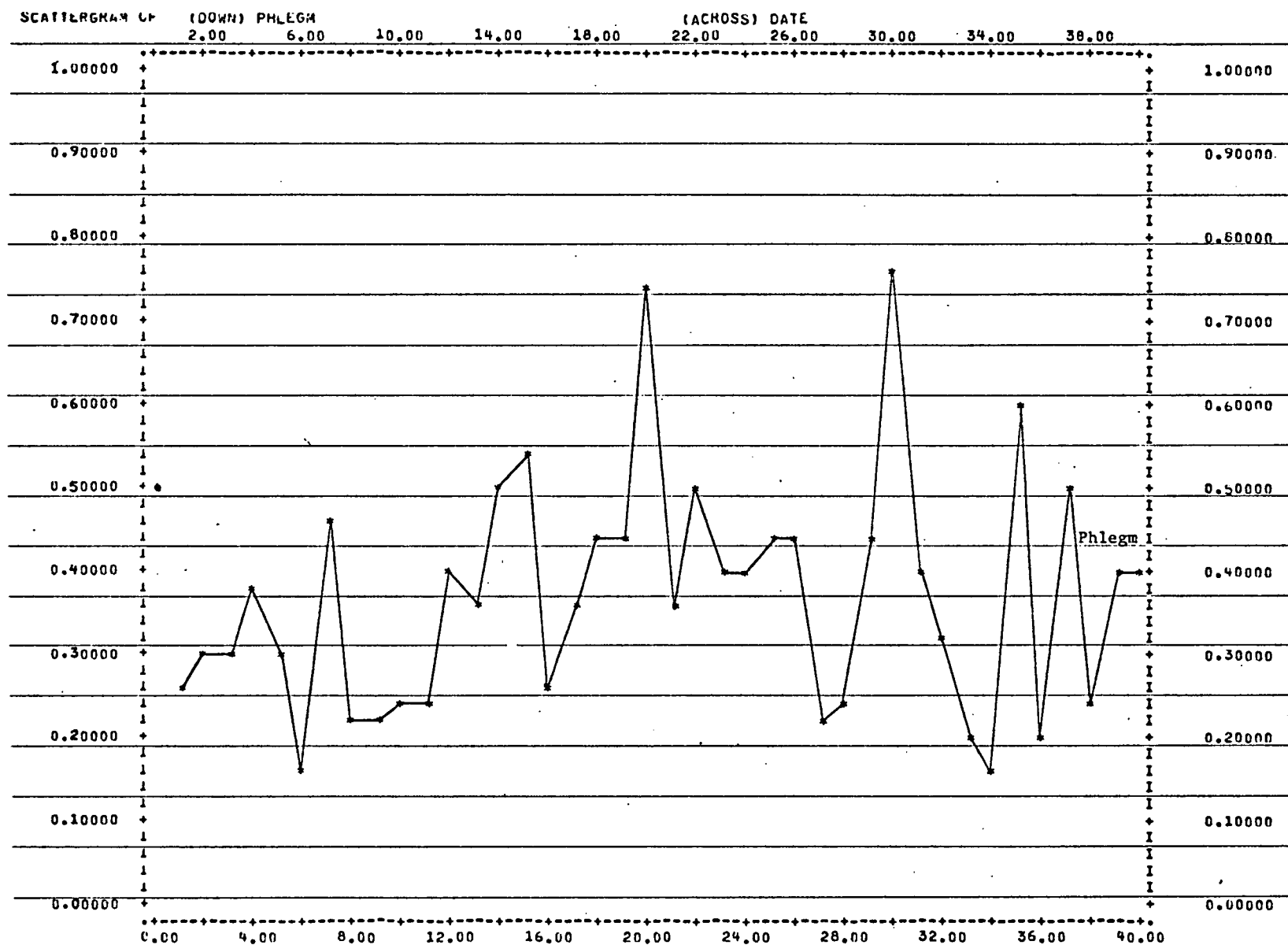
Figure I-9. Proportion of asthma panel reporting phlegm by date.
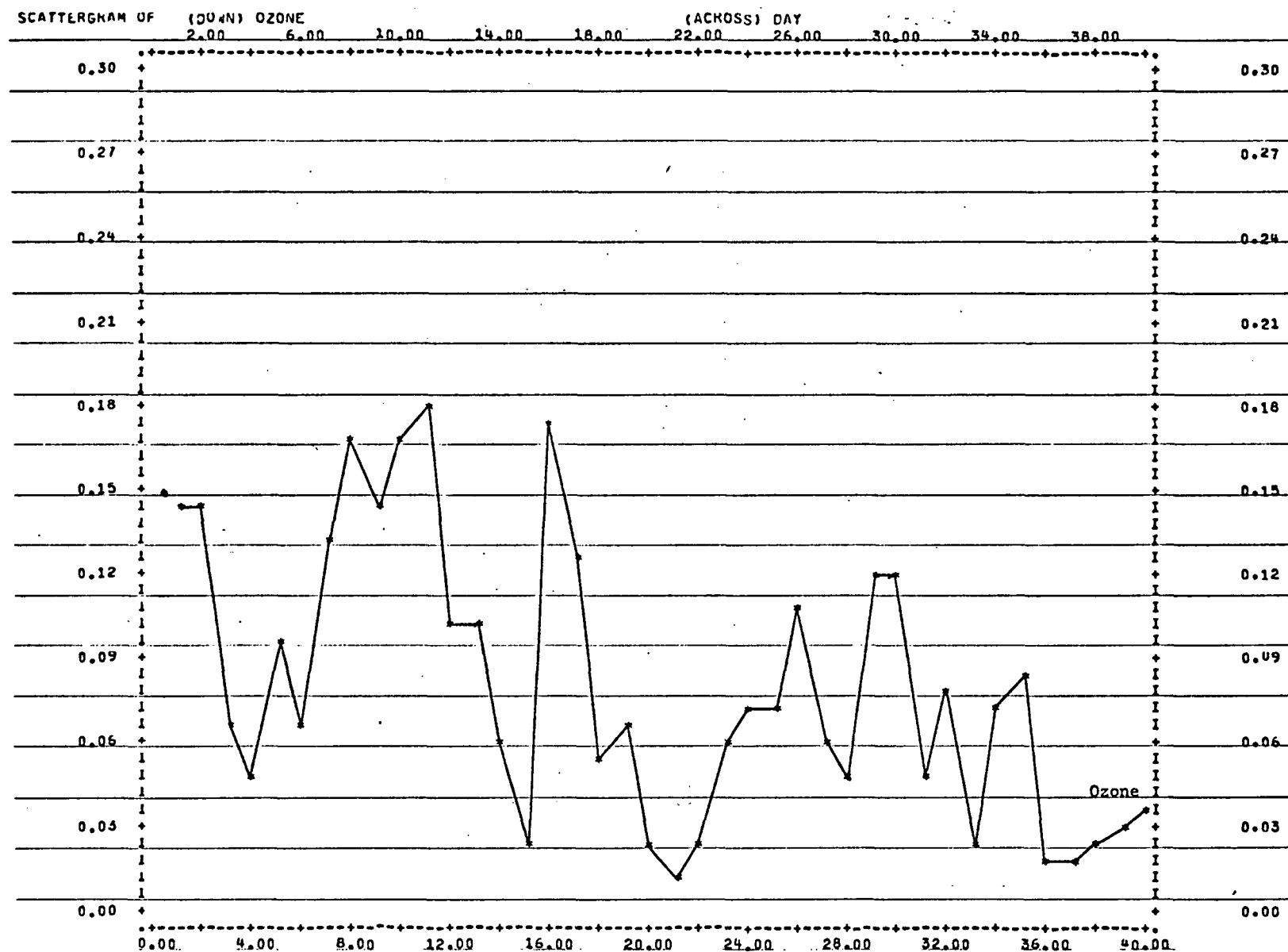
Figure I-10.   Average level of ozone by date: asthma panel.

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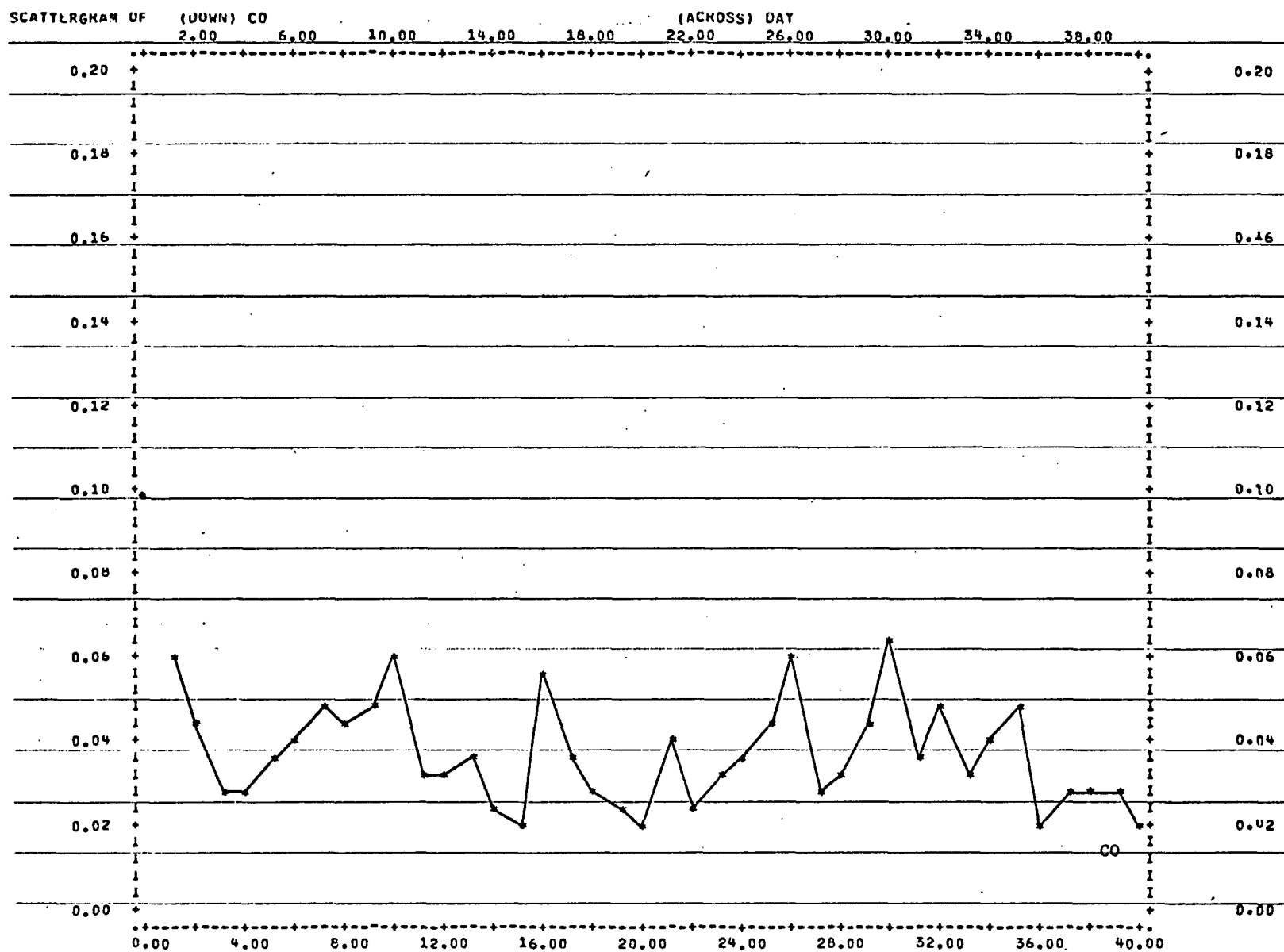
Figure I-11. Average level of carbon monoxide by date: asthma panel.

SCATTERGRAM OF   (DOWN) NO2   (ACROSS) DAY
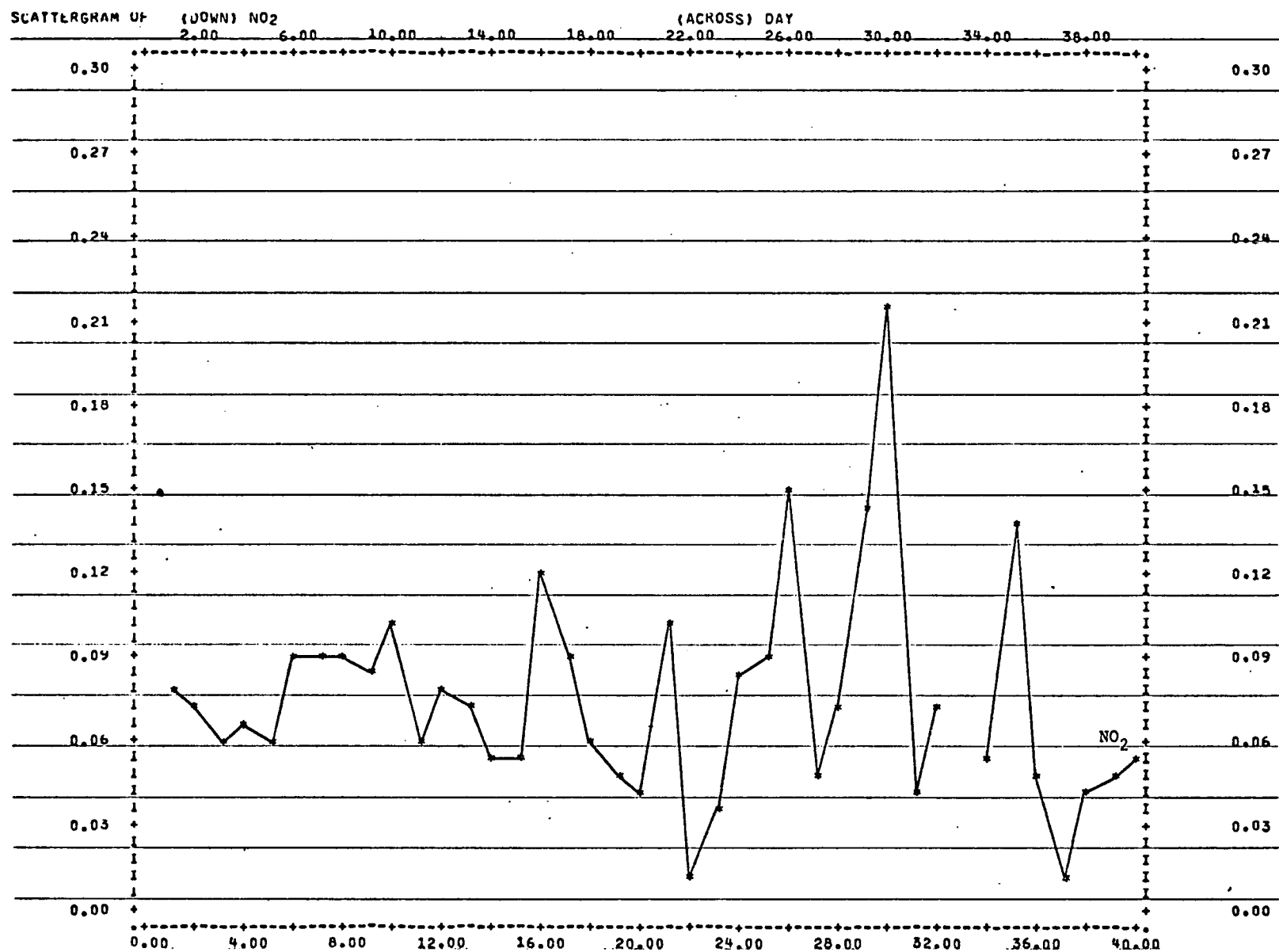
Figure I-12.   Average level of nitrogen dioxide by date: asthma panel.
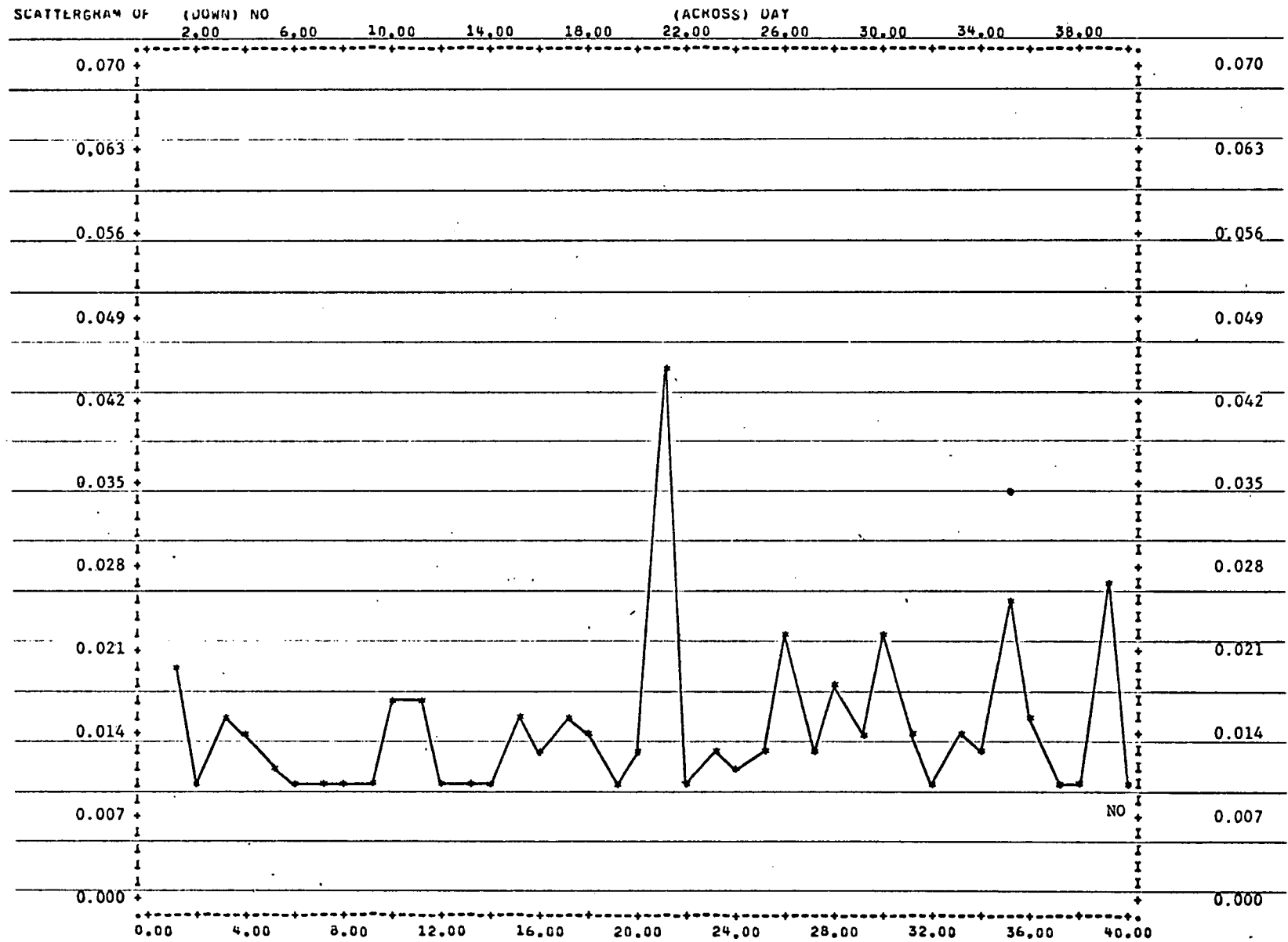
Figure I-13.   Average level of nitric oxides by date: asthma panel.
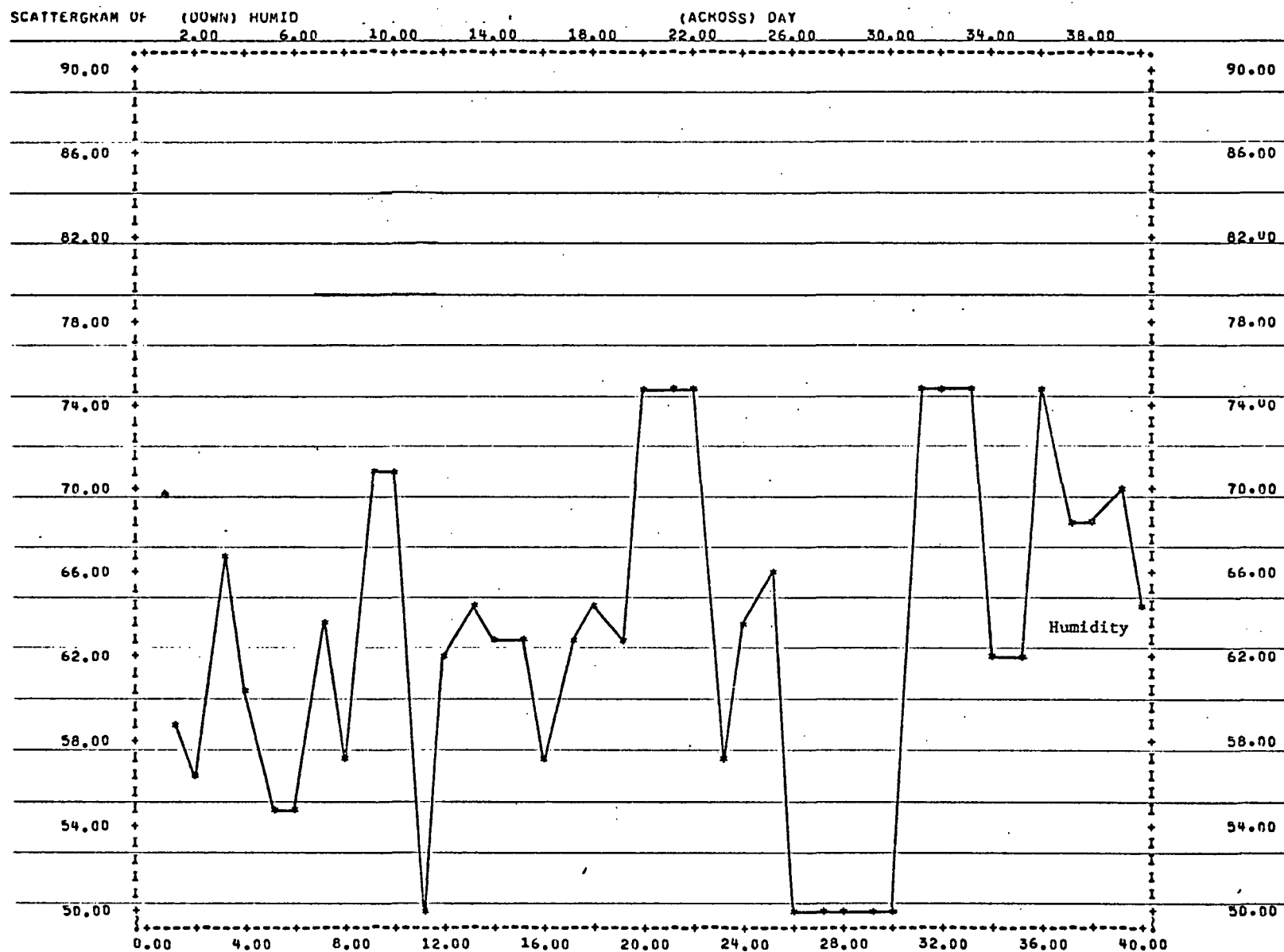
Figure I-14.   Average relative humidity by date: asthma panel.
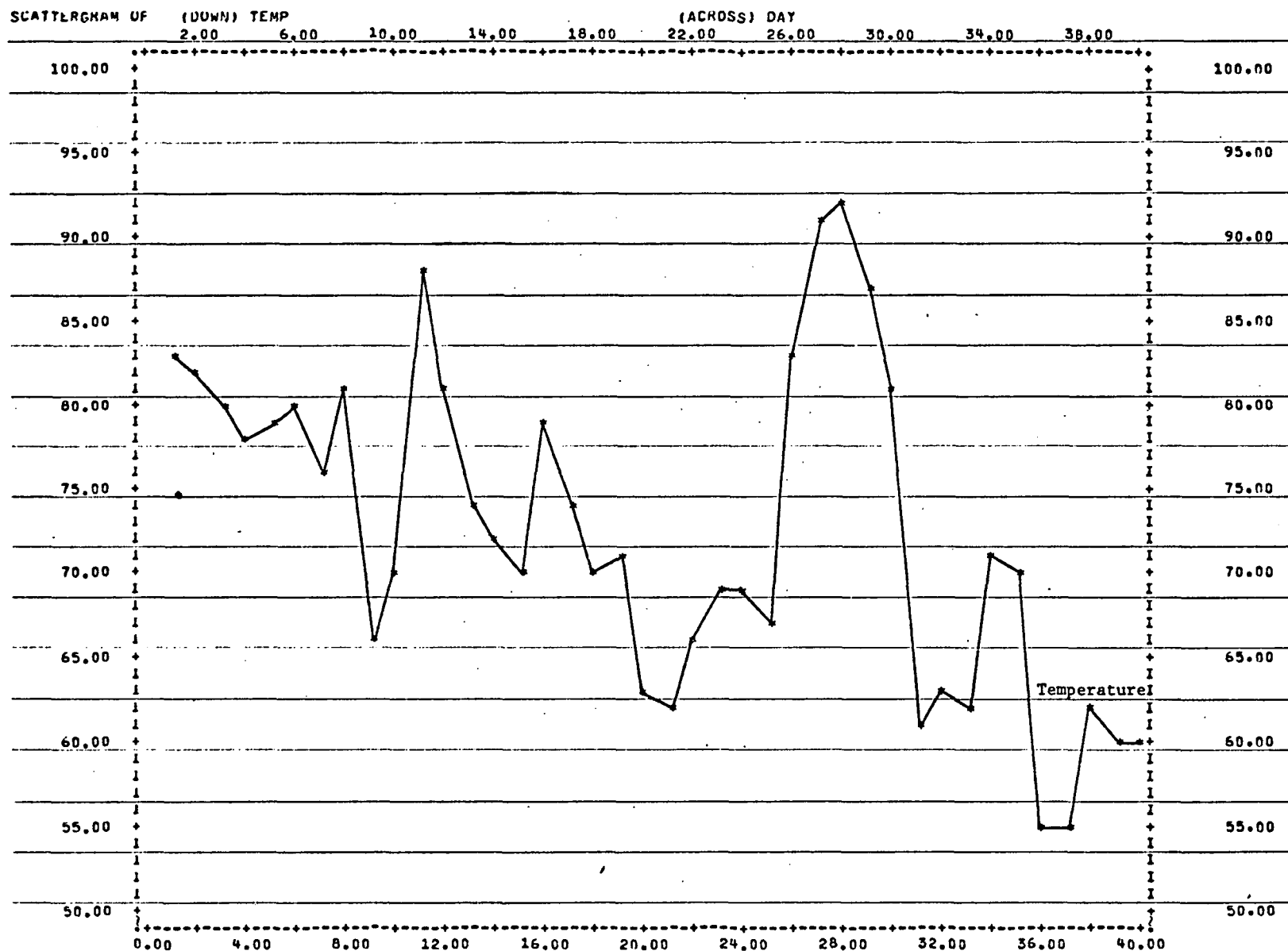
Figure I-15. Average temperature by date: asthma panel.

APPENDIX J

PROPORTION OF OUTDOOR WORKER PANEL REPORTING
DISCOMFORT SYMPTOMS AND WEIGHTED AVERAGES OF
AIR POLLUTION LEVELS CHARTED BY DAY NUMBER

OUTDOOR WORKER PANEL DATA COLLECTION SCHEDULE

Discomfort symptoms and aerometric data were collected from members of the outdoor worker panel on the dates shown below. This was during late summer and fall of 1974.

Day Number	Date	Sub-Panel	Day Number	Date	Sub-Panel
1	September 11	1*, 2*	29	October 15	3
2	12	1	30	16	3
3	13	1	31	17	3
4	14	1	32	18	3
5	16	1	33	19	3
6	17	1	34	21	3
7	18	1*	35	22	3
8	19	1	36	23	3
9	20	1	37	24	3
10	21	1	38	25	3
11	23	1, 3**, 4**	39	28	4
			40	29	4
12	24	1	41	30	4
13	25	1	42	31	1***, 2*** 3***, 4
14	26	1			
15	27	1	43	November 1	4
16	28	1	44	2	4
17	30	2	45	4	4
18	October 1	2	46	5	4
19	2	2	47	6	4
20	3	2	48	7	1***, 2*** 3***, 4***
21	4	2			
22	5	2	49	8	4
23	7	2	50	9	4
24	8	2	51	11	4
25	9	2	52	12	4
26	10	2	53	13	4
27	11	2	54	14	4
28	12	2			

*Clinical pre-surveillance tests and symptom interviews.
**Clinical pre-surveillance tests.
***Clinical post-surveillance tests and symptom interviews.

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The proportions of outdoor worker panelists who reported discomfort symptoms are shown in Figures J-1 through J-9 for each of these 54 days.

In order to account for the effects on health associated with exposure to air pollutants and to humidity and temperature at the time panelists were asked to complete Daily Symptom Records (shown in Appendix F), weighted averages had to be developed. In doing so, the hour at which each panelist reported for testing was noted and the aerometric values for that hour were included in the weighted average for that day. The weighted averages of exposure are shown in Figures J-10 through J-15.

Figure J-1. Proportion of outdoor worker panel reporting eye discomfort by date.

Figure J-2. Proportion of outdoor worker panel reporting throat irritation by date.
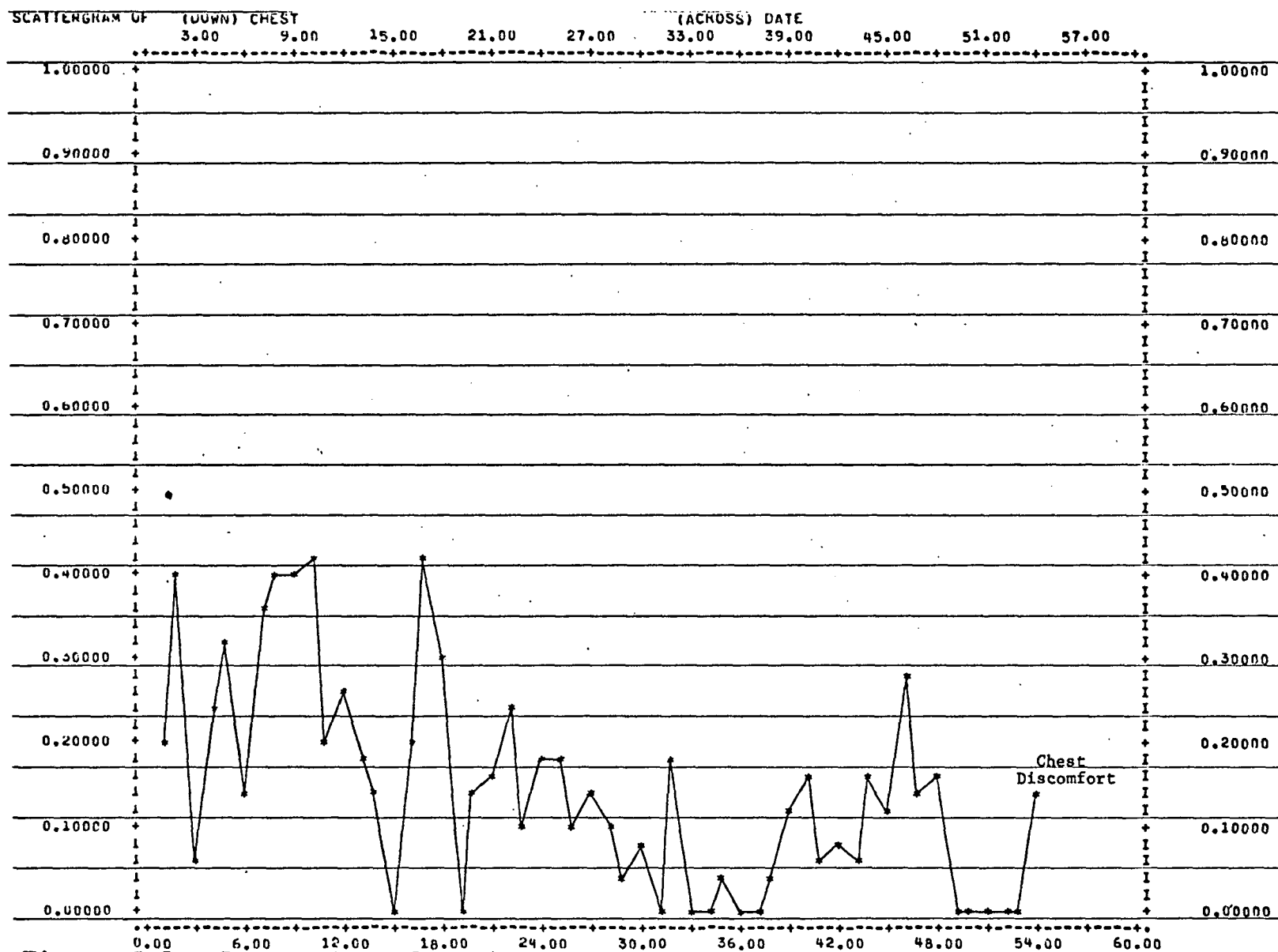
Figure J-3. Proportion of outdoor worker panel reporting chest discomfort by date.

Figure J-4. Proportion of outdoor worker panel reporting headache by date.

SCATTERGRAM OF   (DOWN) NAUSEA   (ACROSS) DATE
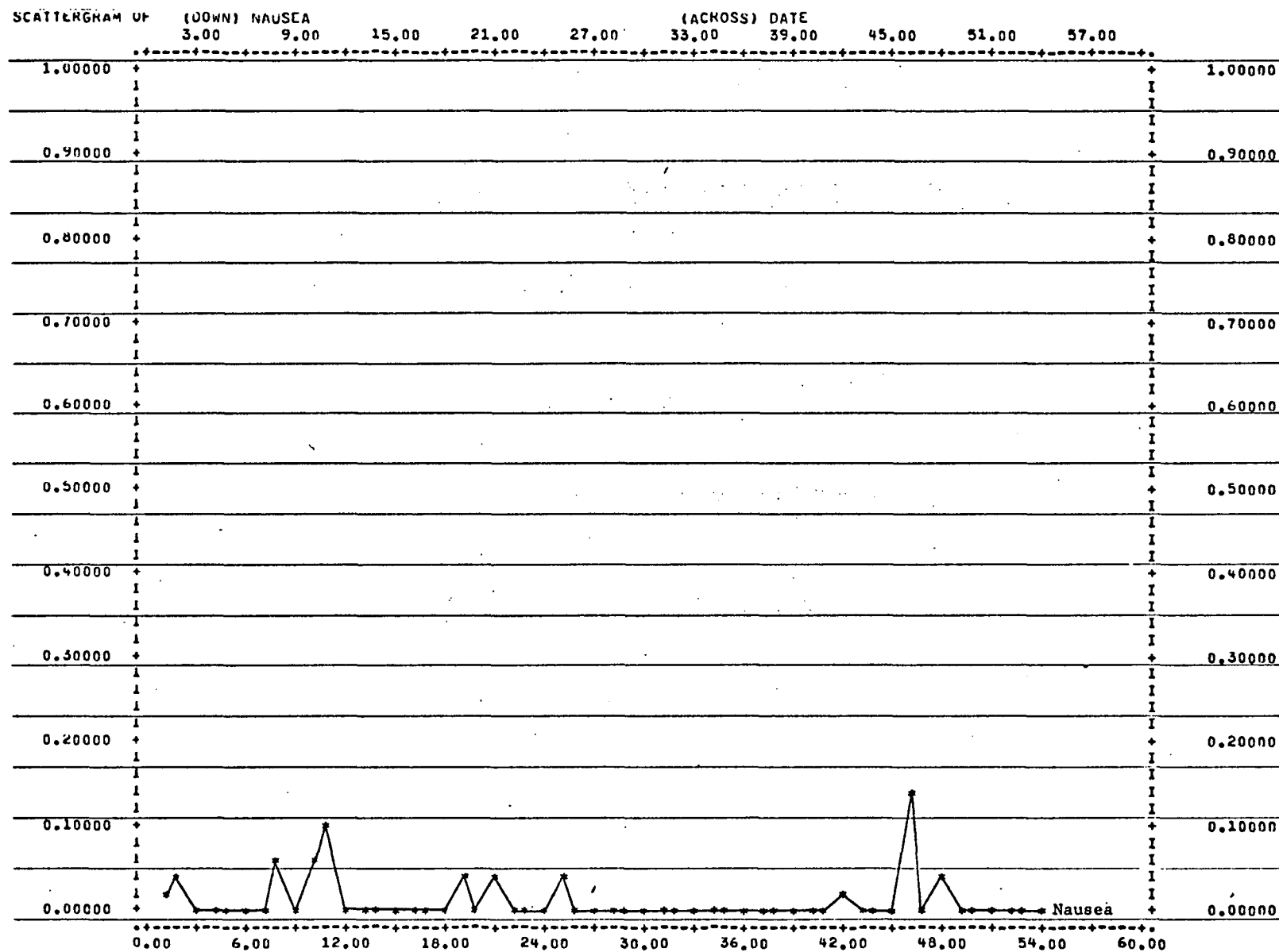
Figure J-5. Proportion of outdoor worker panel reporting nausea by date.

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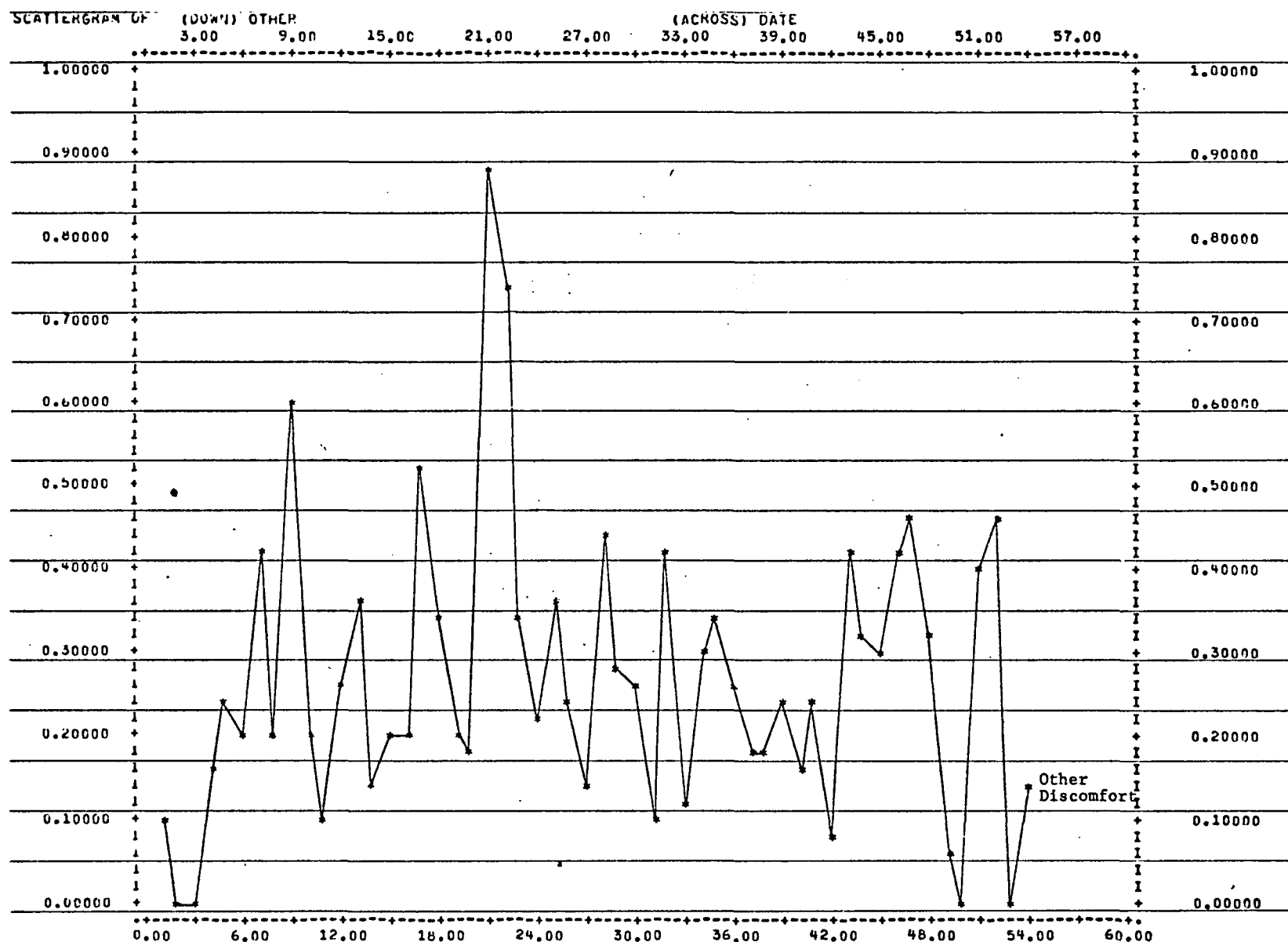
Figure J-6. Proportion of outdoor worker panel reporting other discomfort by date.
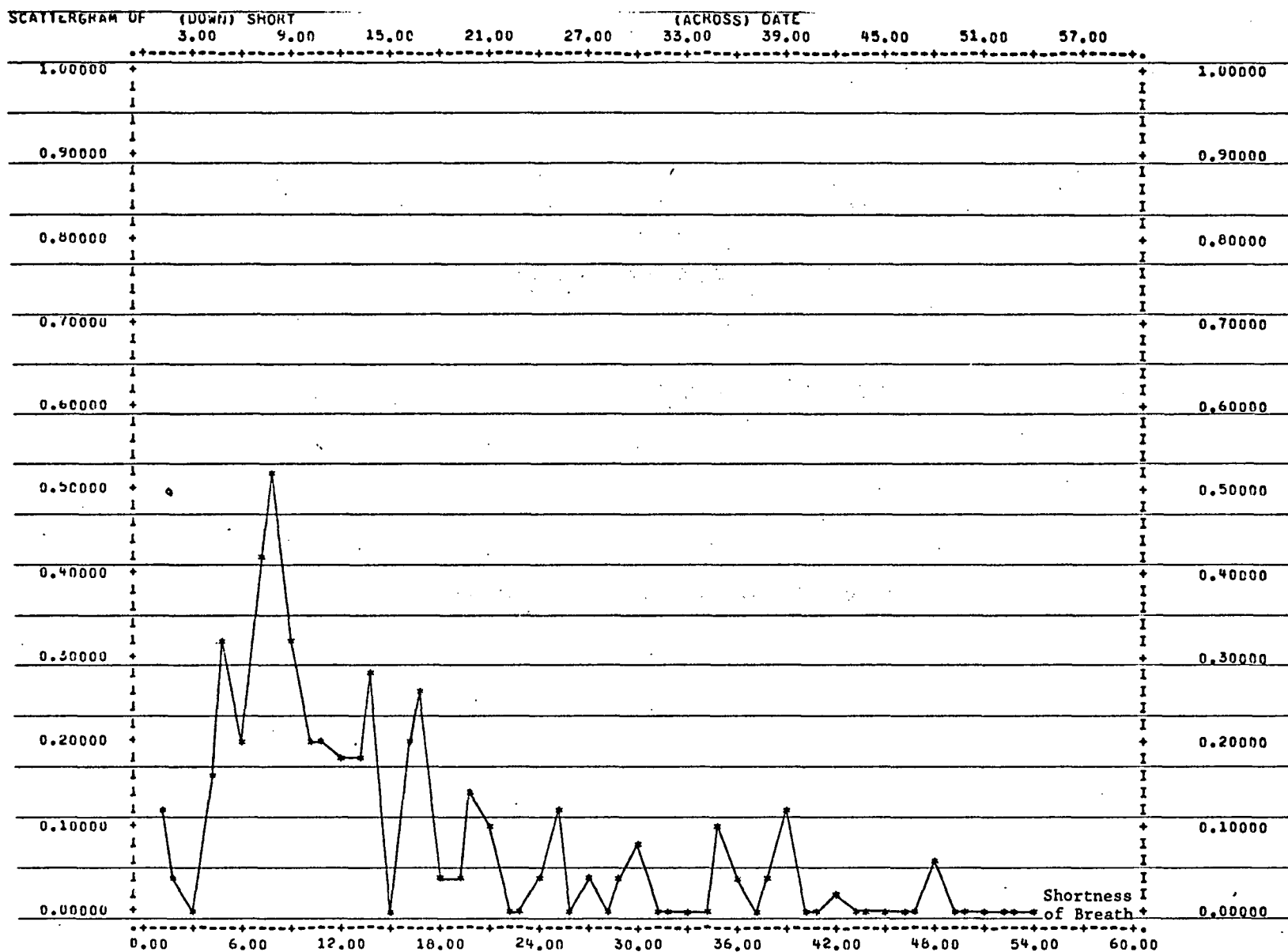
Figure J-7. Proportion of outdoor worker panel reporting shortness of breath by date.
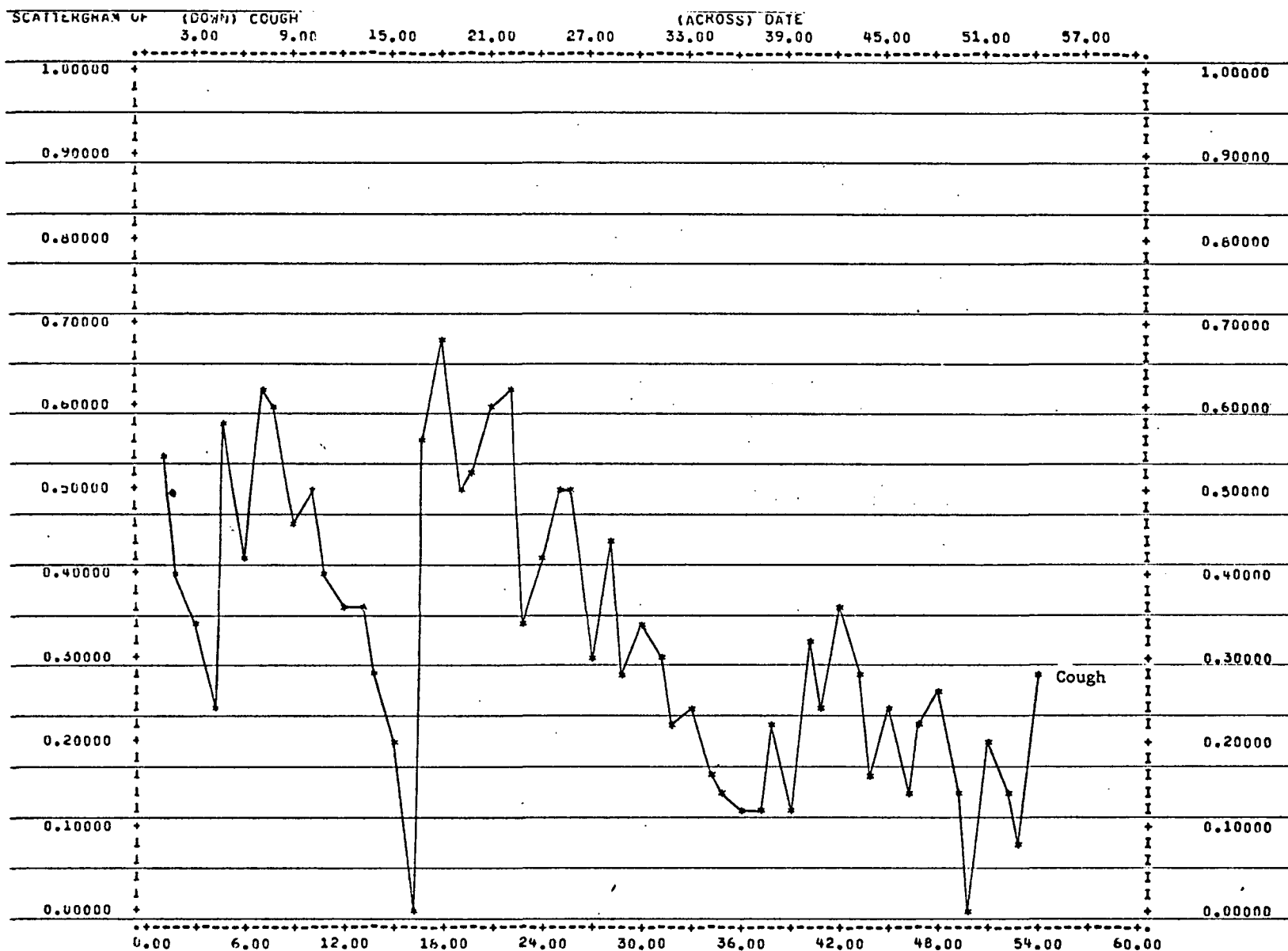
Figure J-8. Proportion of outdoor worker panel reporting cough by date.
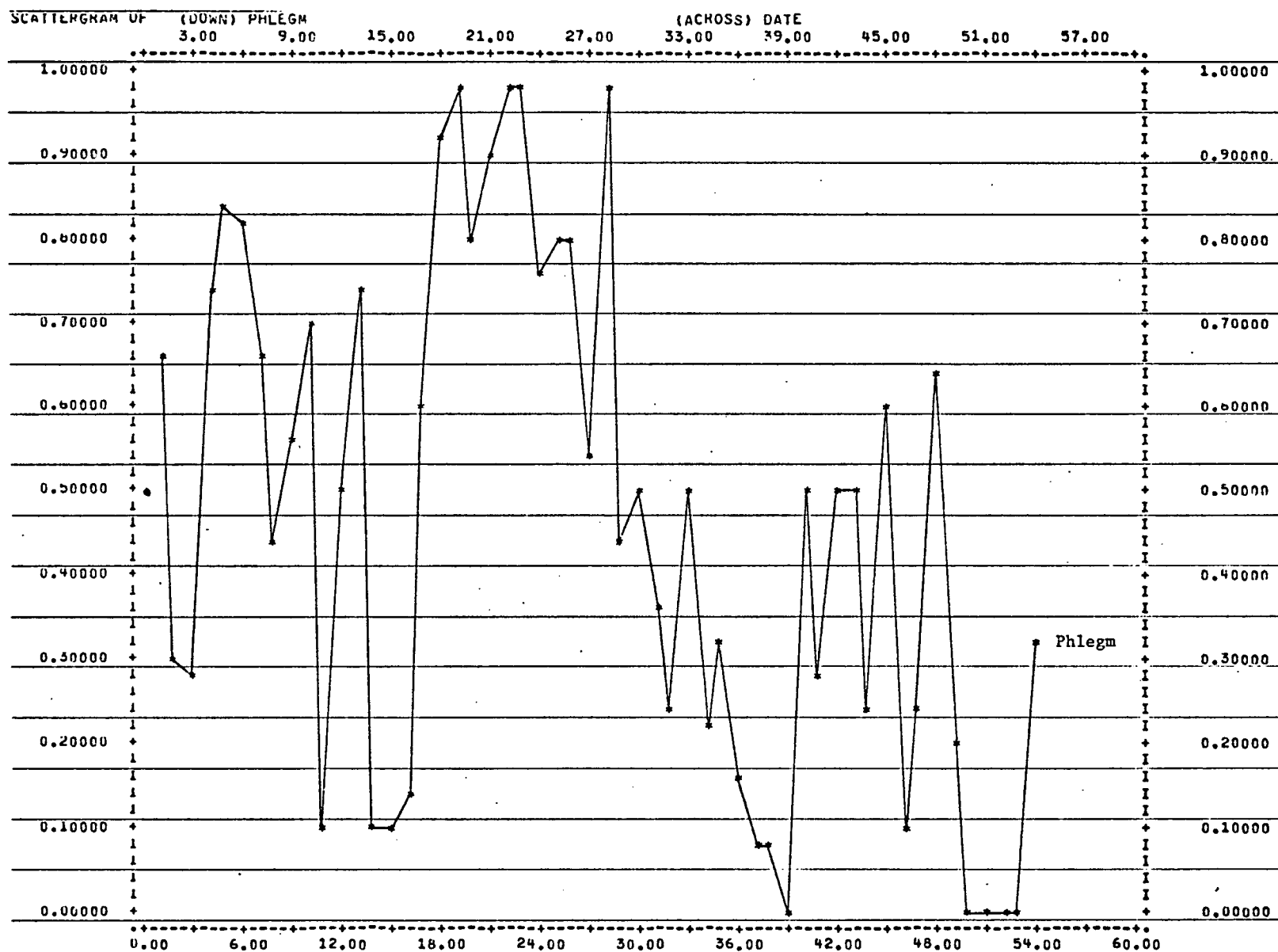
Figure J-9. Proportion of outdoor worker panel reporting phlegm by date.
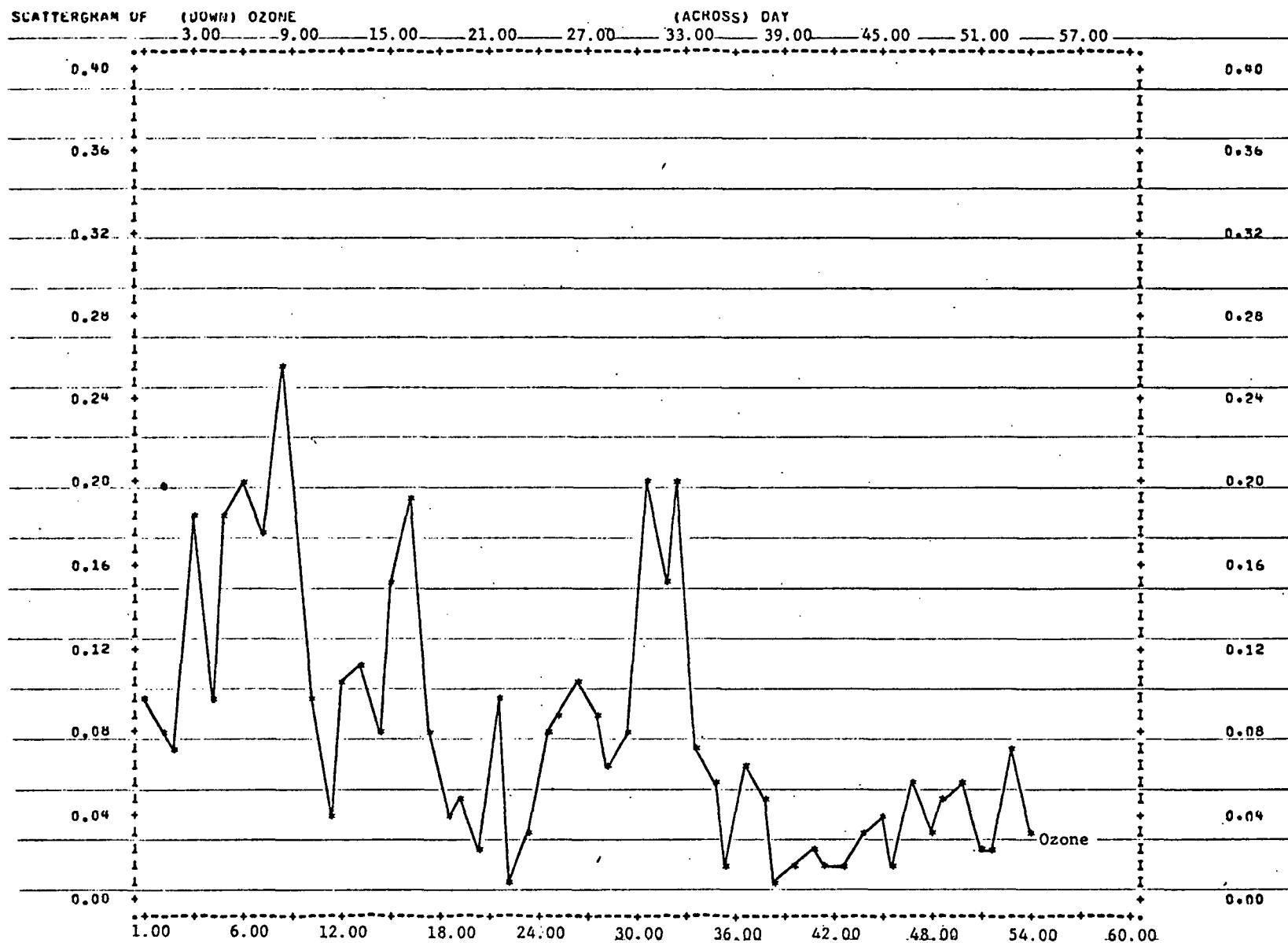
Figure J-10. Average level of ozone by date: outdoor worker panel.
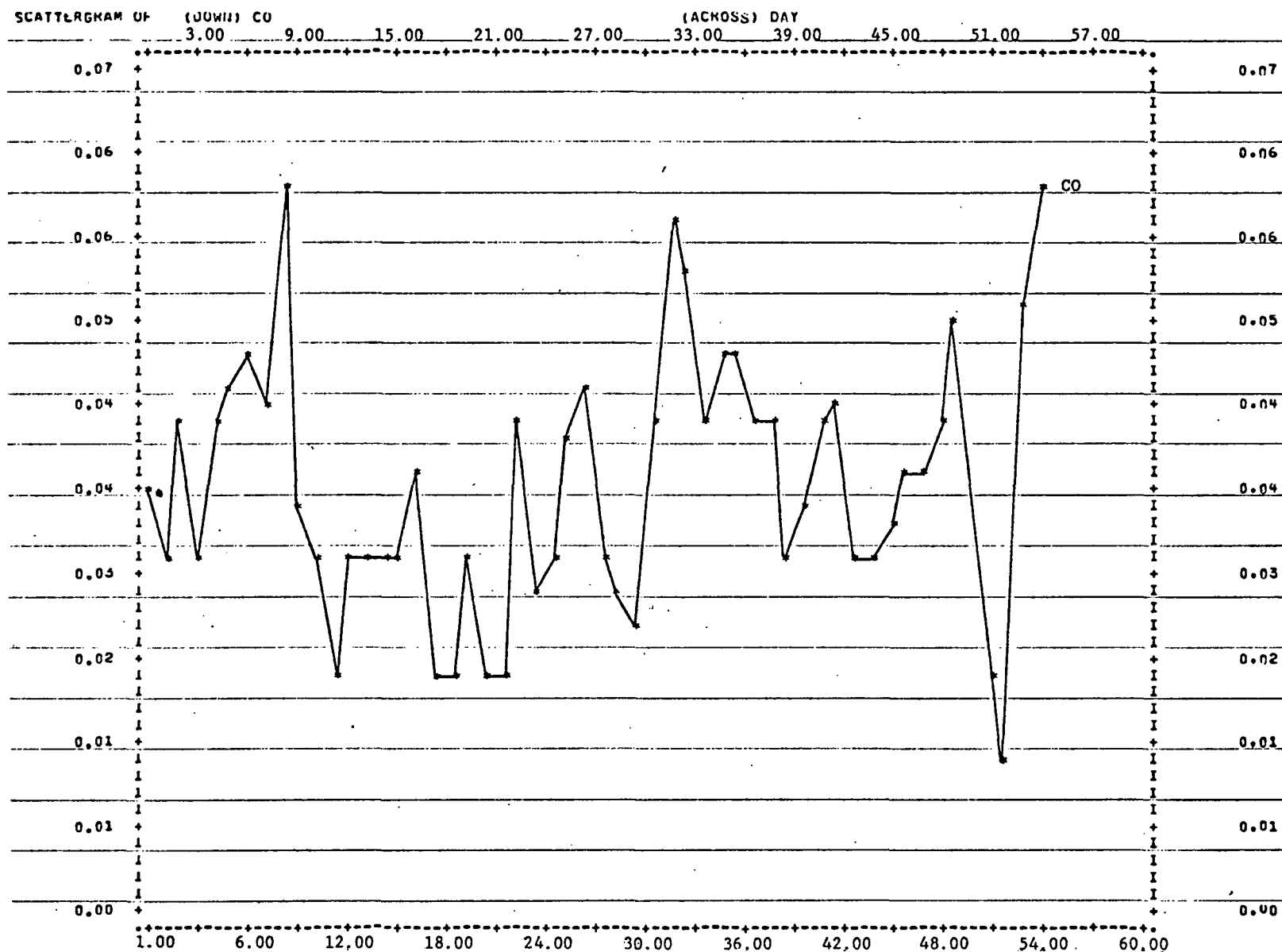
Figure J-11. Average level of carbon monoxide by date: outdoor worker panel.
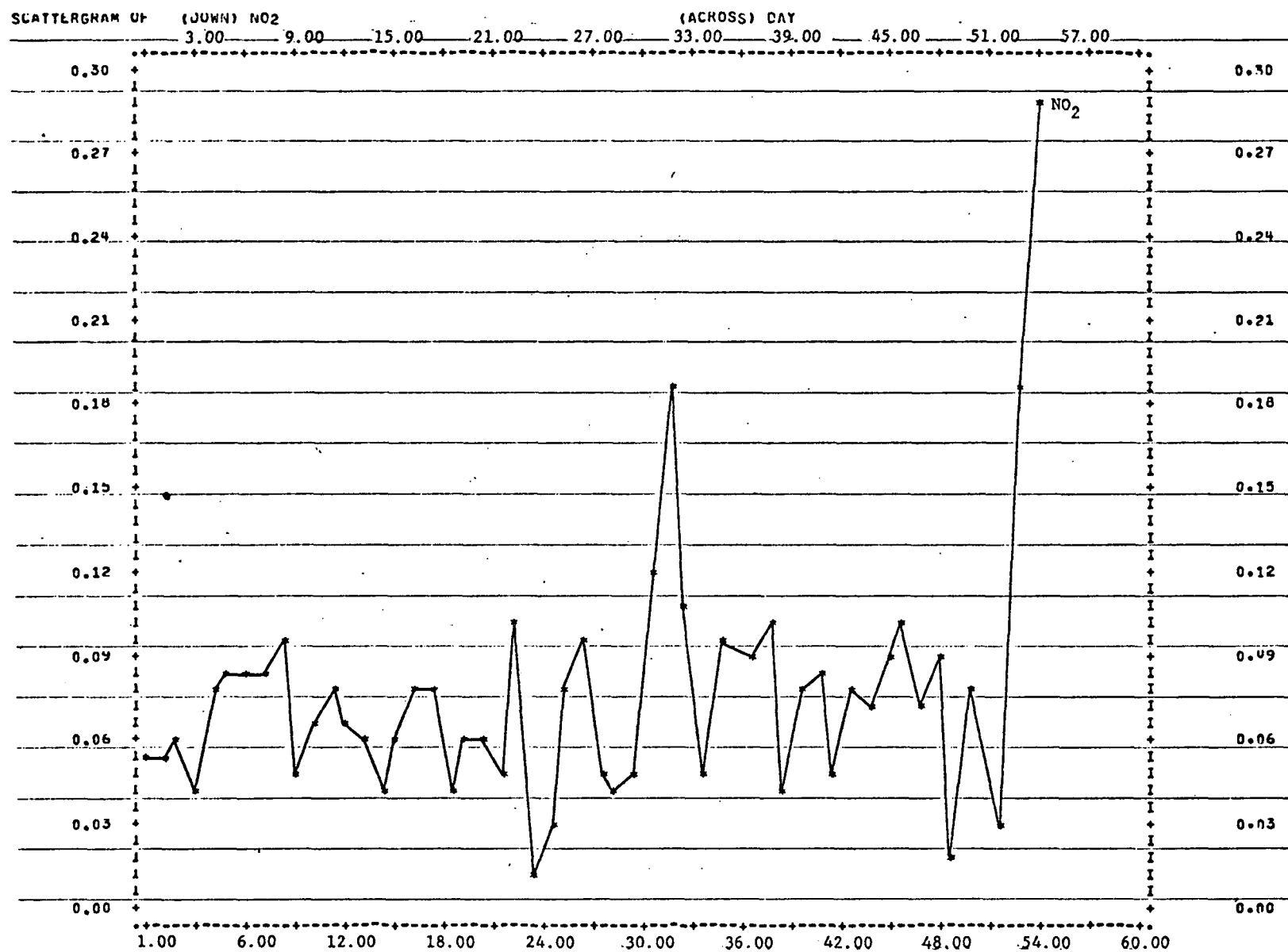
Figure J-12. Average level of nitrogen dioxide by date: outdoor worker panel.
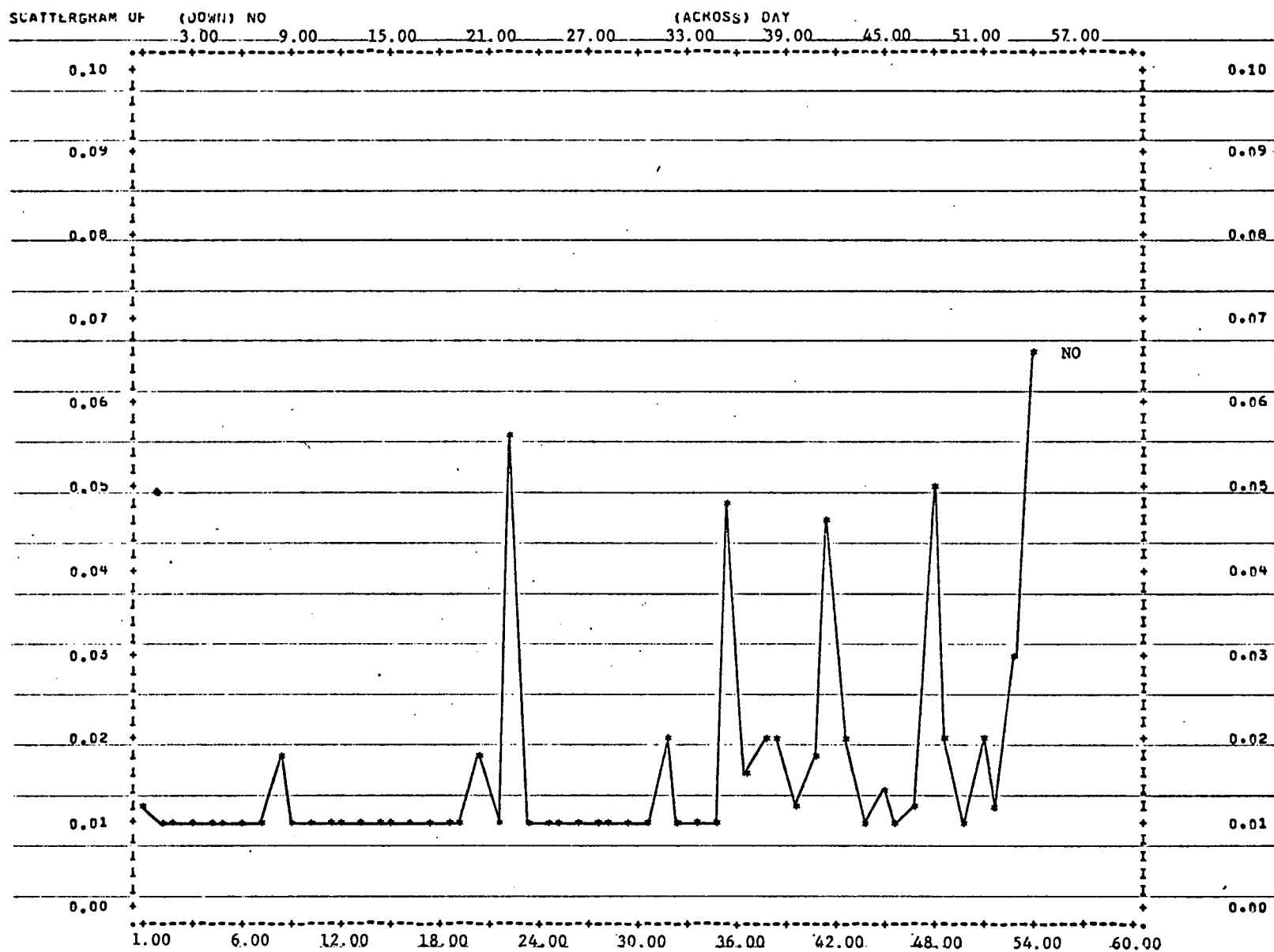
Figure J-13. Average level of nitric oxides by date: outdoor worker panel.

SCATTERGRAM OF   (DOWN) HUMID   (ACROSS) DAY
              ——3.00——— 9.00——15.00——21.00——27.00——33.00—— 39.00——45.00——51.00——57.00——
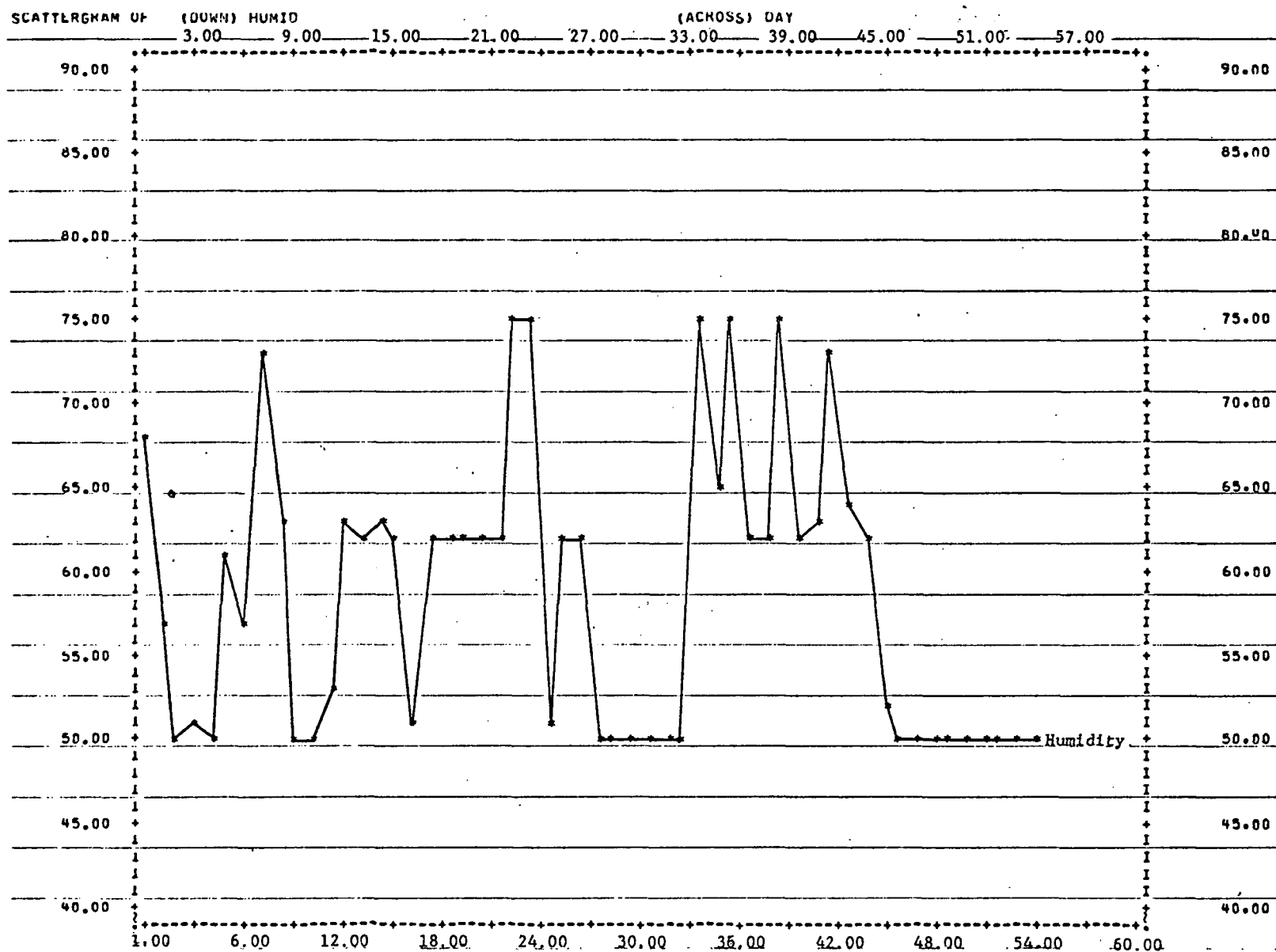
Figure J-14.   Average level of relative humidity by date: outdoor worker panel.

SCATTERGRAM OF (DOWN) TEMP   (ACROSS) DAY
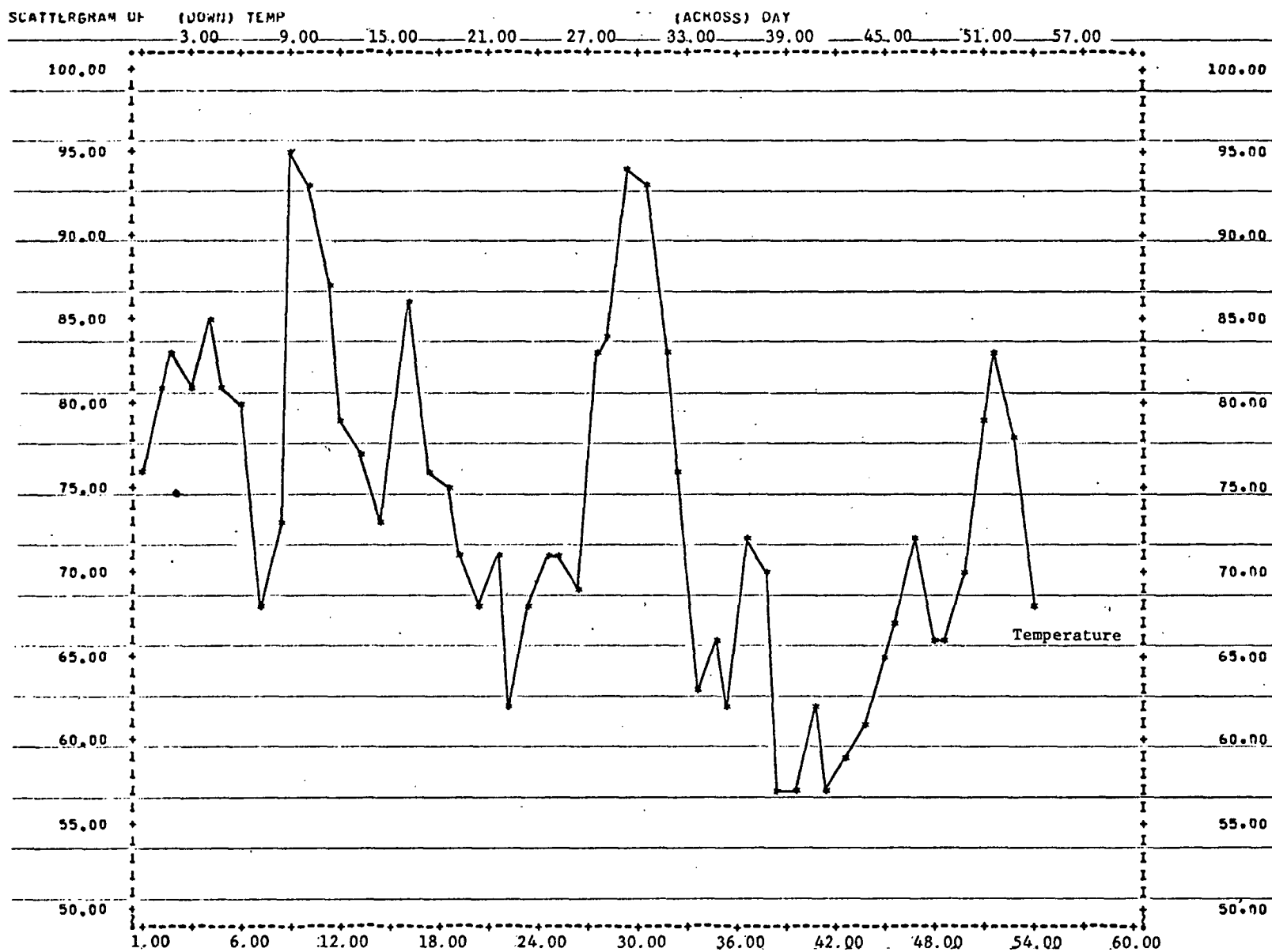
Figure J-15. Average temperature by date: outdoor worker panel.

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APPENDIX K

PROPORTION OF BRONCHITIS PANEL REPORTING
DISCOMFORT SYMPTOMS AND WEIGHTED AVERAGES OF
AIR POLLUTION LEVELS CHARTED BY DAY NUMBER

BRONCHITIS PANEL DATA COLLECTION SCHEDULE

Discomfort symptoms and aerometric data were collected from members of the bronchitis panel on the dates shown below. This was during late summer and fall of 1974.

Day Number	Date
1	September 4
2	5
3	18
4	24
5	25
5	October 1
7	9
8	15
9	16
10	18
11	22
12	25

The proportions of bronchitis panelists who reported discomfort symptoms are shown in Figures K-1 through K-9 for each of these 12 days.

In order to account for the effects on health associated with exposure to air pollutants and to humidity and temperature at the time panelists were asked to complete Daily Symtpom Records (shown in Appendix F), weighted averages had to be developed. In doing so, the hour at which each panelist reported for testing was noted and the aerometric values for that hour were included in the weighted average for that day. The weighted averages of exposure are shown in Figures K-10 through K-15.

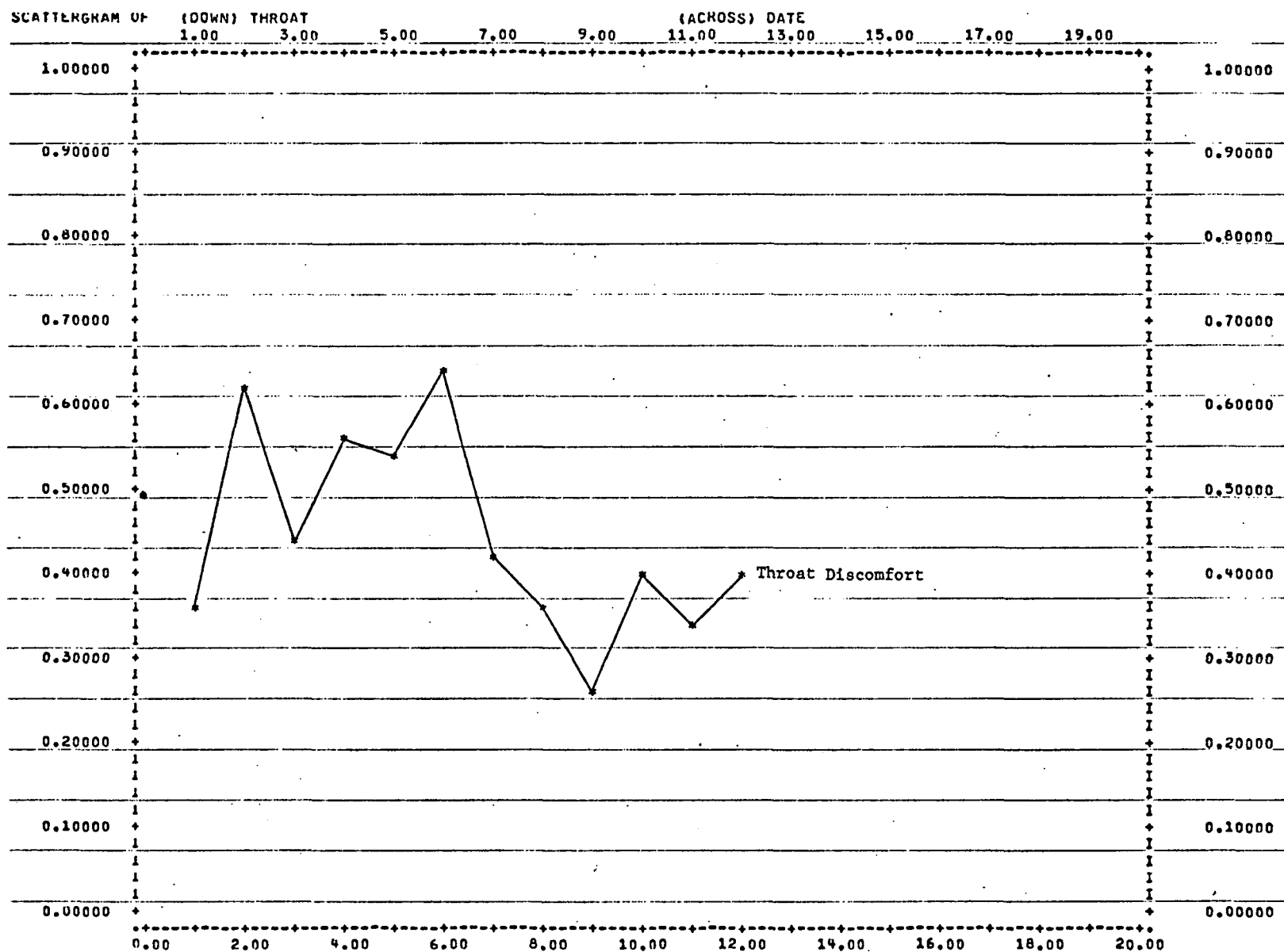SCATTERGRAM OF   (DOWN) EYES   (ACROSS) DATE
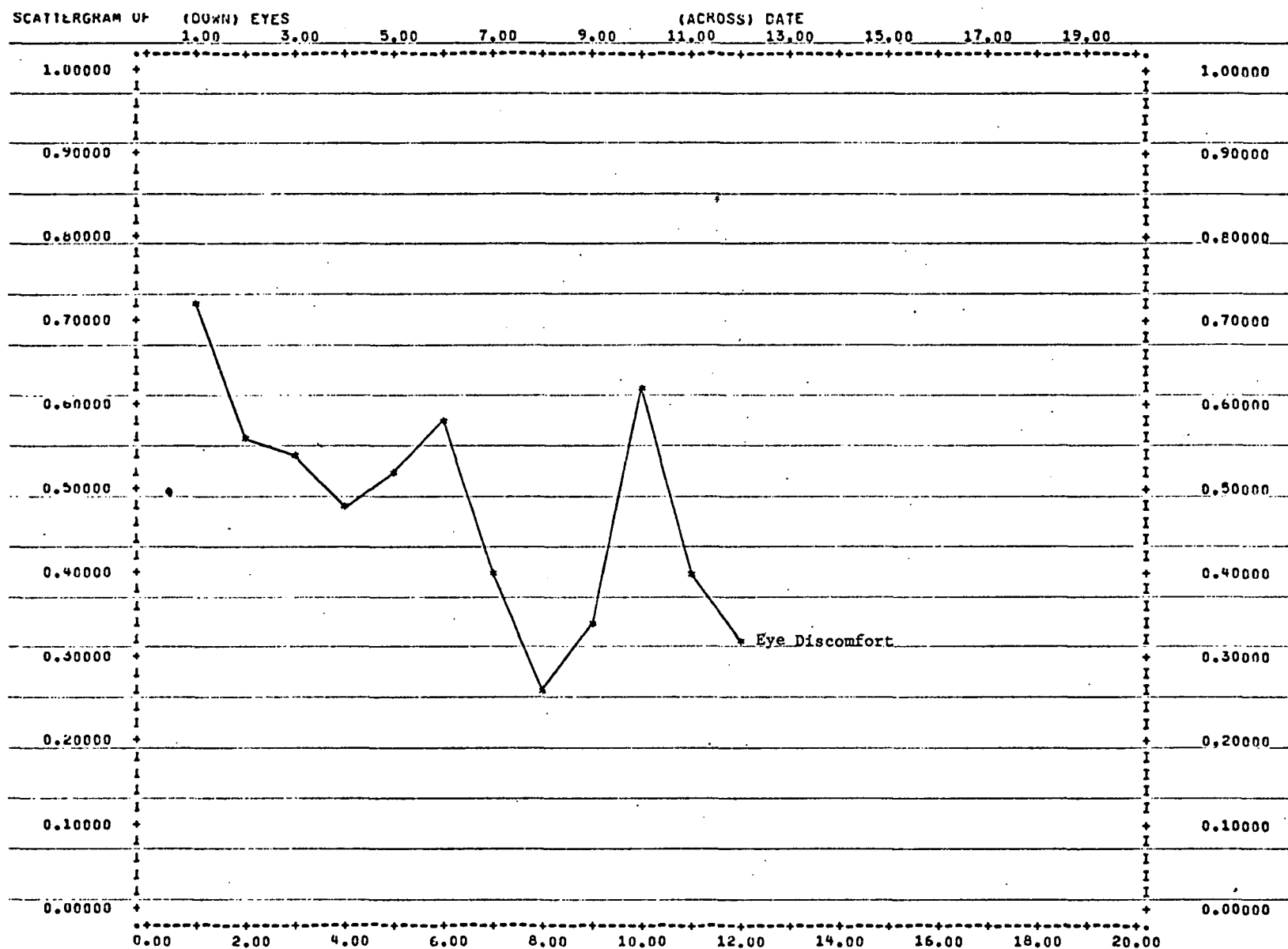
Figure K-1.   Proportion of bronchitis panel reporting eye discomfort by date.

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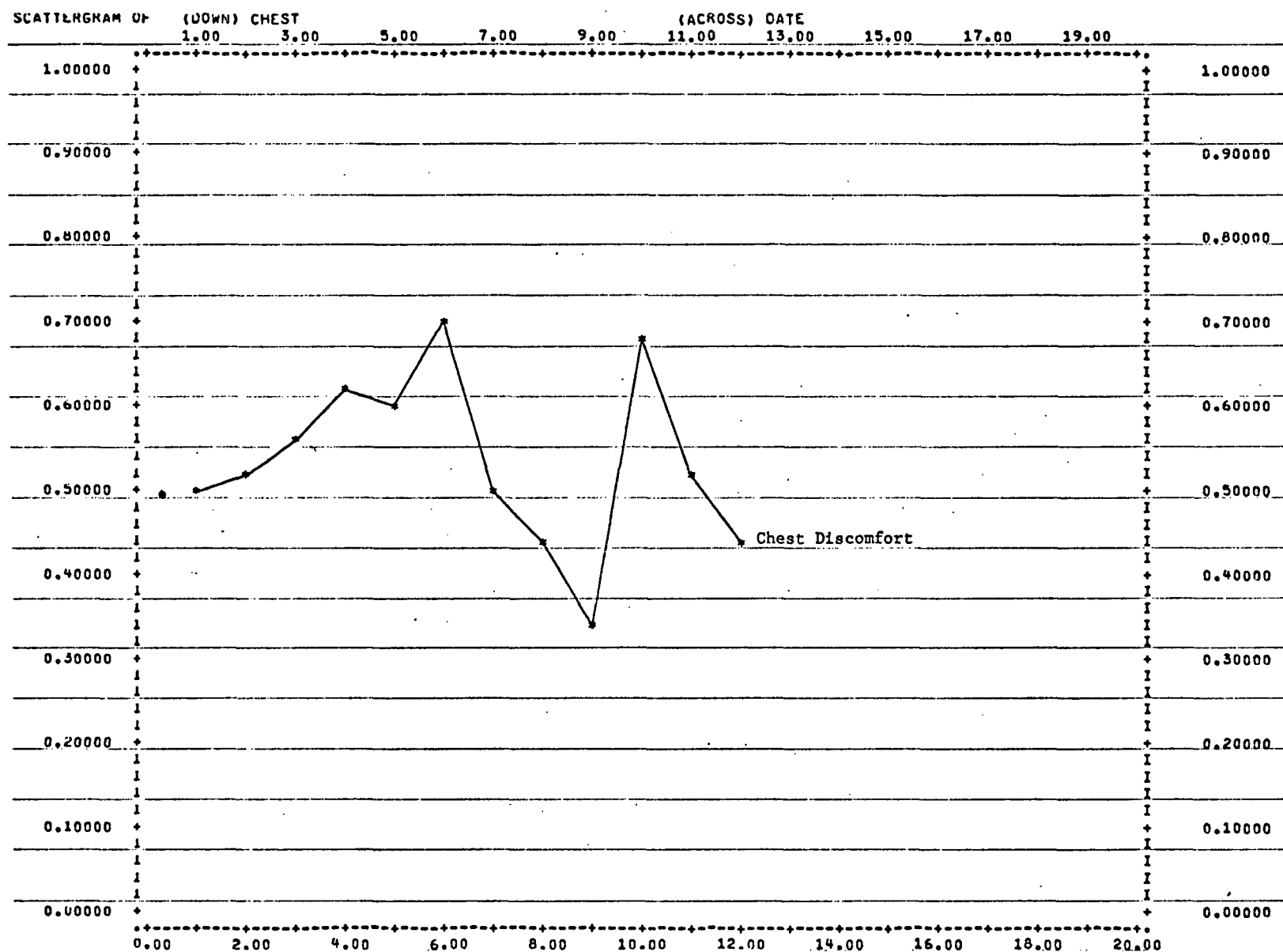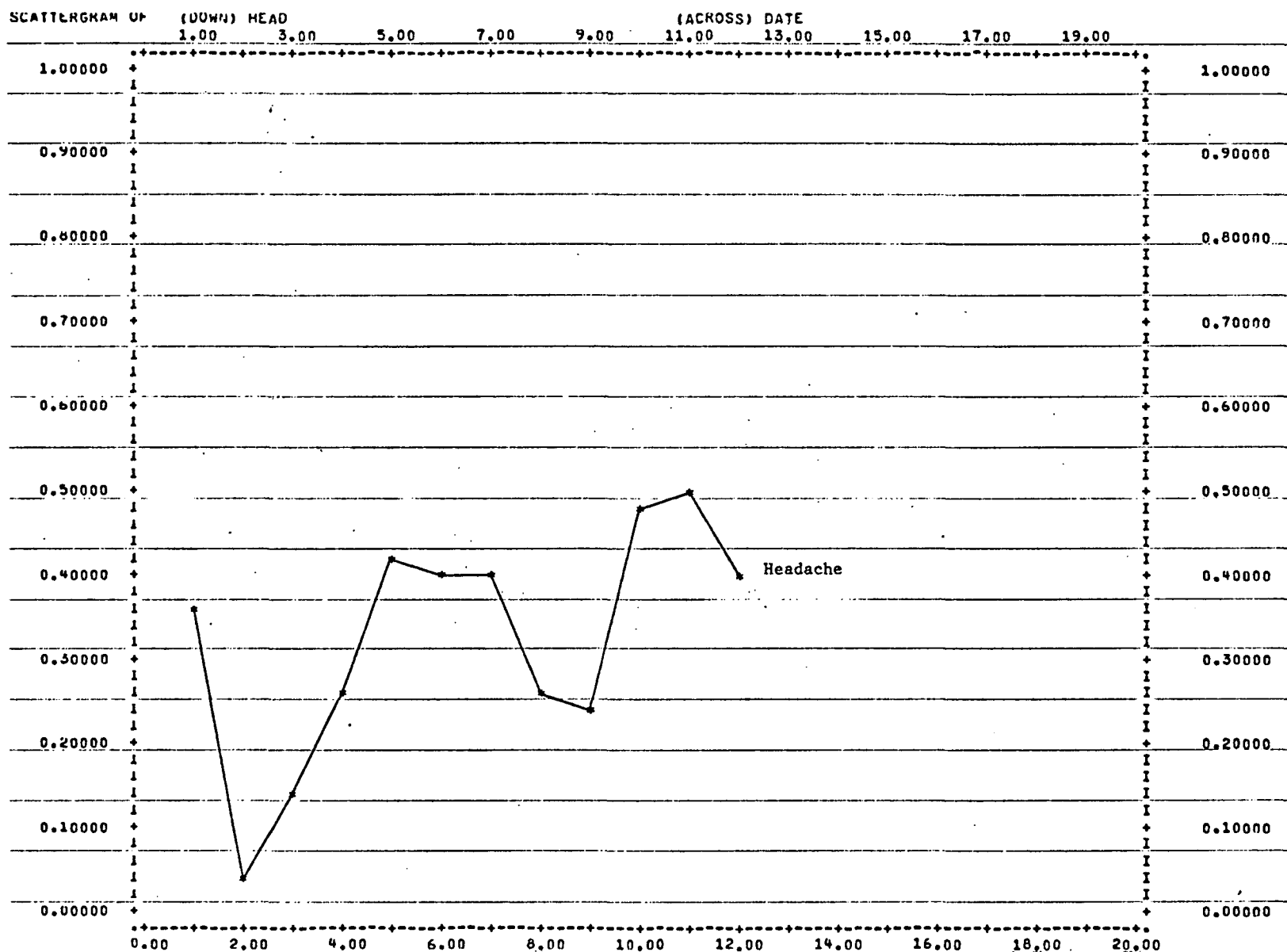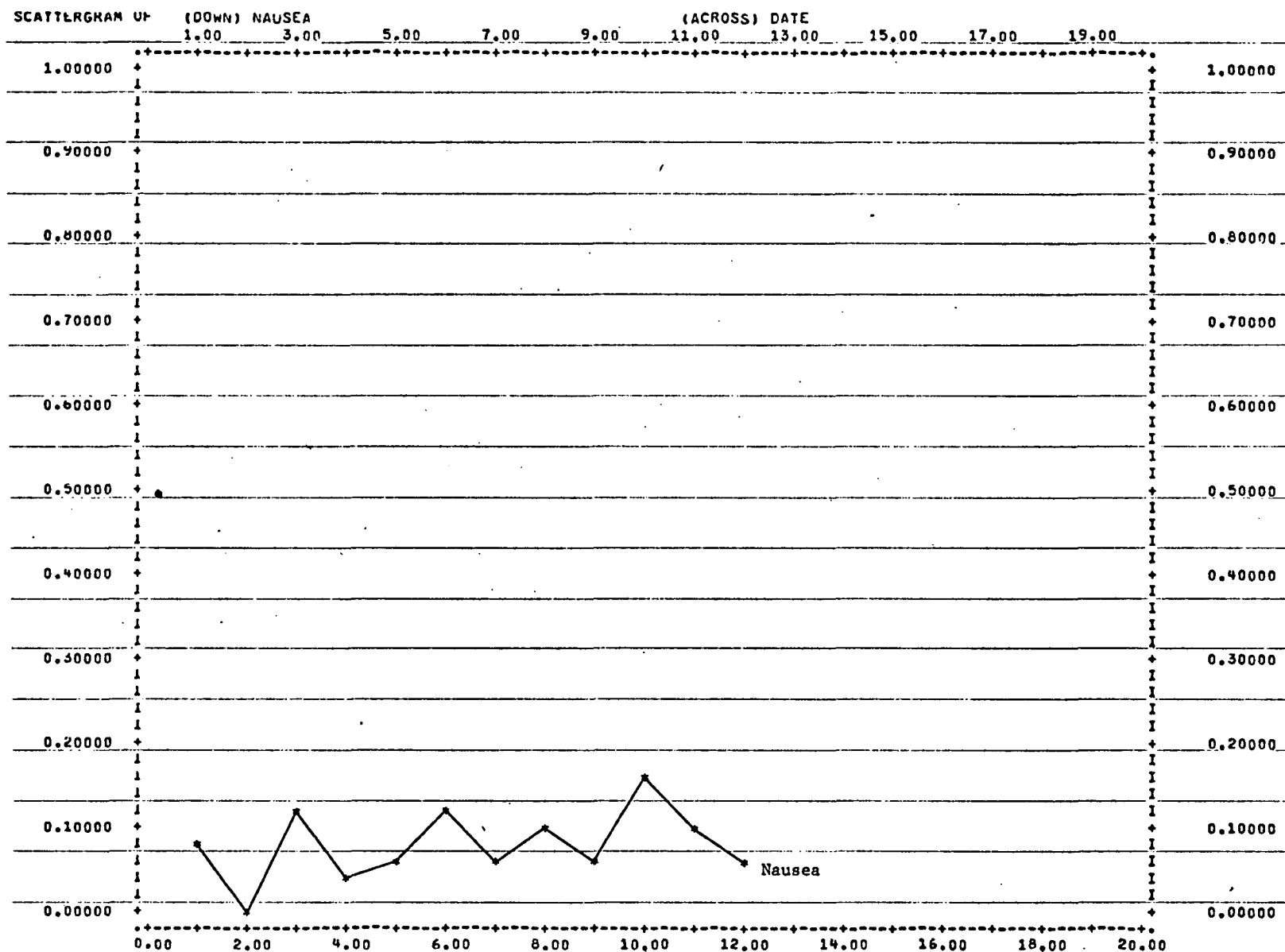Figure K-2. Proportion of bronchitis panel reporting throat discomfort by date.

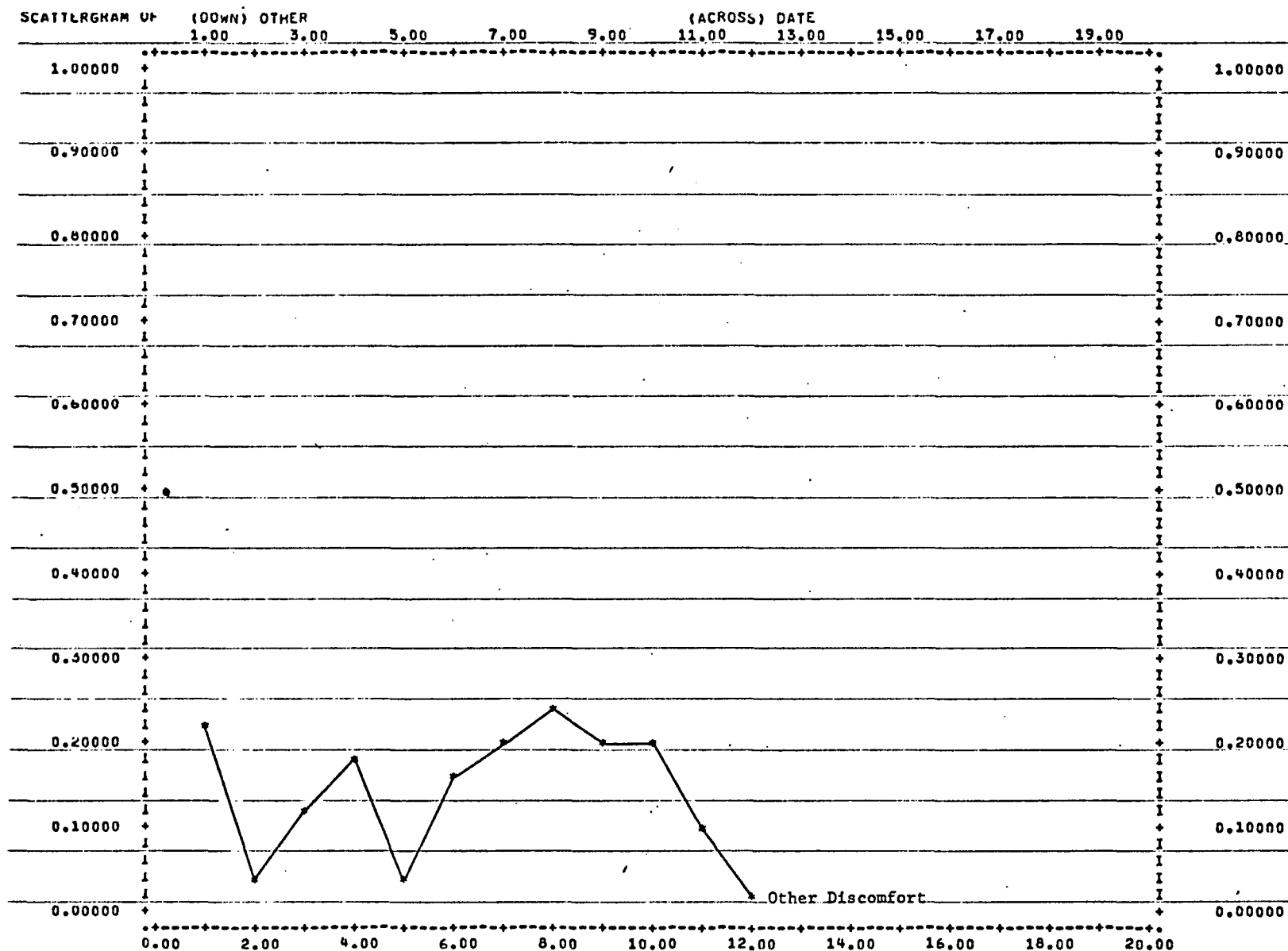SCATTERGRAM OF   (DOWN) CHEST   (ACROSS) DATE
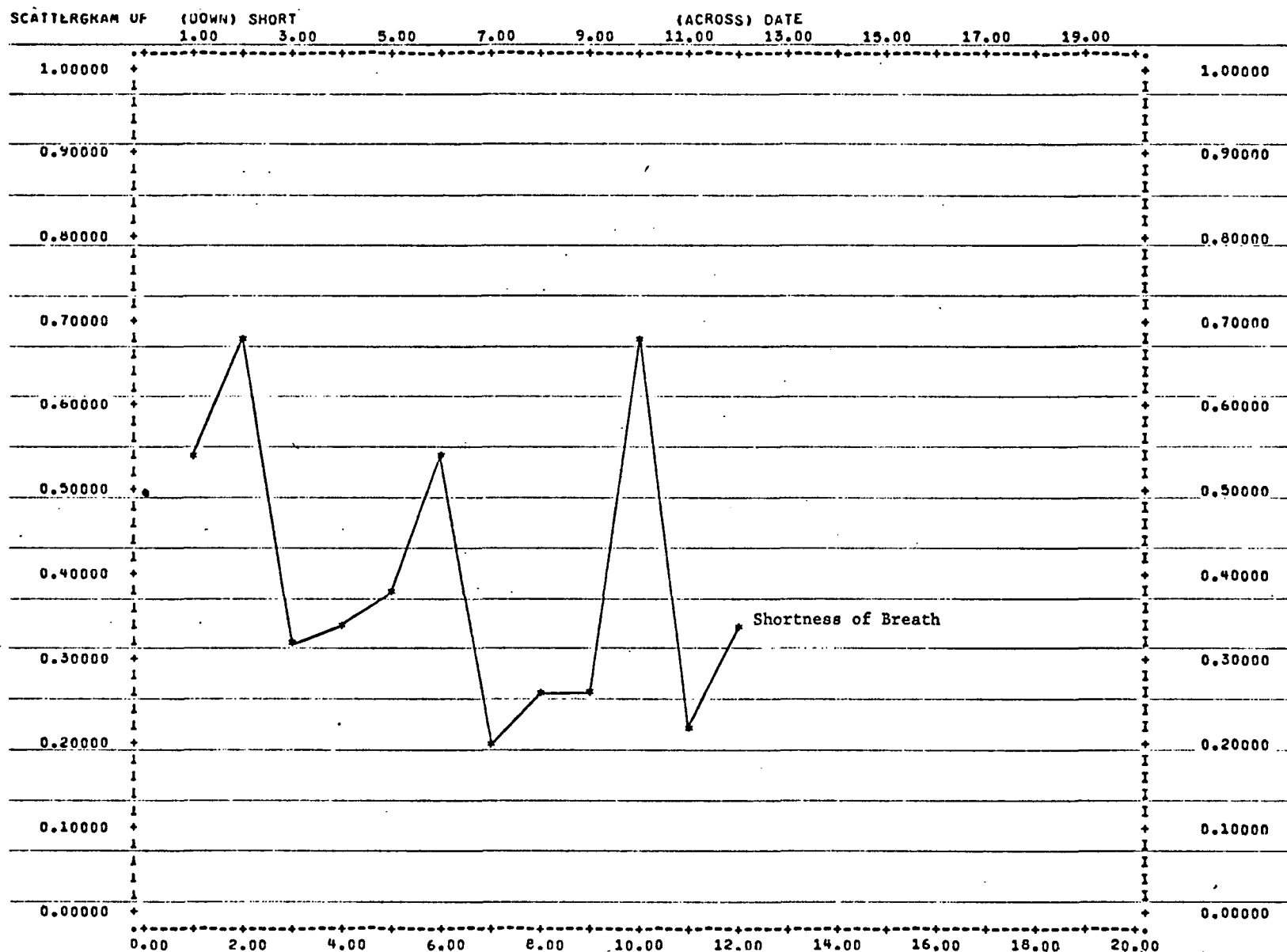
Figure K-3. Proportion of bronchitis panel reporting chest discomfort by date.

Figure K-4. Proportion of bronchitis panel reporting headache by date.

SCATTLRGRAM UF (DOWN) NAUSEA (ACROSS) DATE

1.00 3.00 5.00 7.00 9.00 11.00 13.00 15.00 17.00 19.00

1.00000 .... 1.00000

0.90000 .... 0.90000

0.80000 .... 0.80000

0.70000 .... 0.70000

0.60000 .... 0.60000

0.50000 .... 0.50000

0.40000 .... 0.40000

0.30000 .... 0.30000

0.20000 .... 0.20000

0.10000 .... 0.10000

Nausea

0.00000 .... 0.00000

0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00

Figure K-5.   Proportion of bronchitis panel reporting nausea by date.

Figure K-6. Proportion of bronchitis panel reporting other discomfort by date.

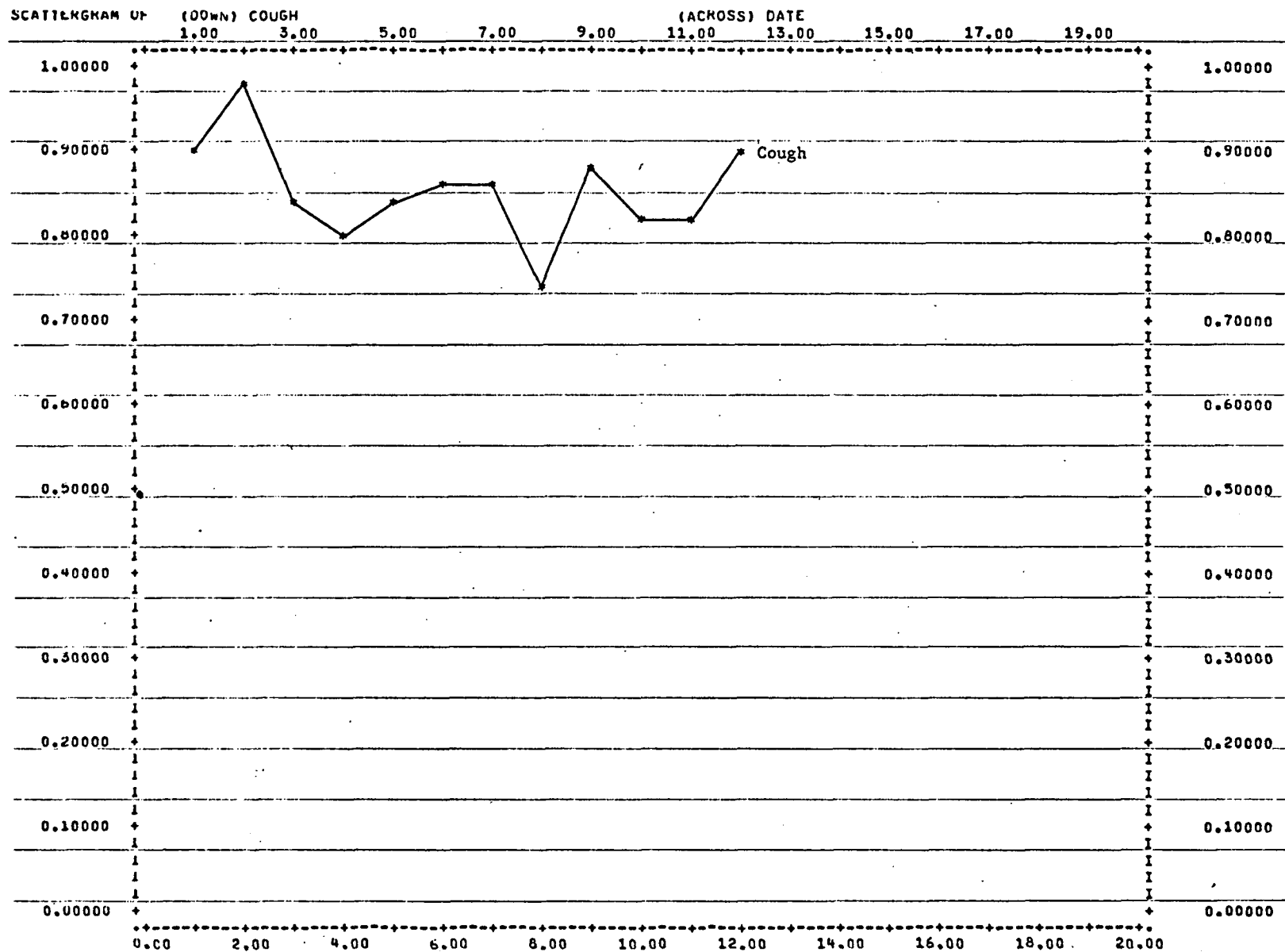Figure K-7.   Proportion of bronchitis panel reporting shortness of breath by date.

Figure K-8. Proportion of bronchitis panel reporting cough by date.
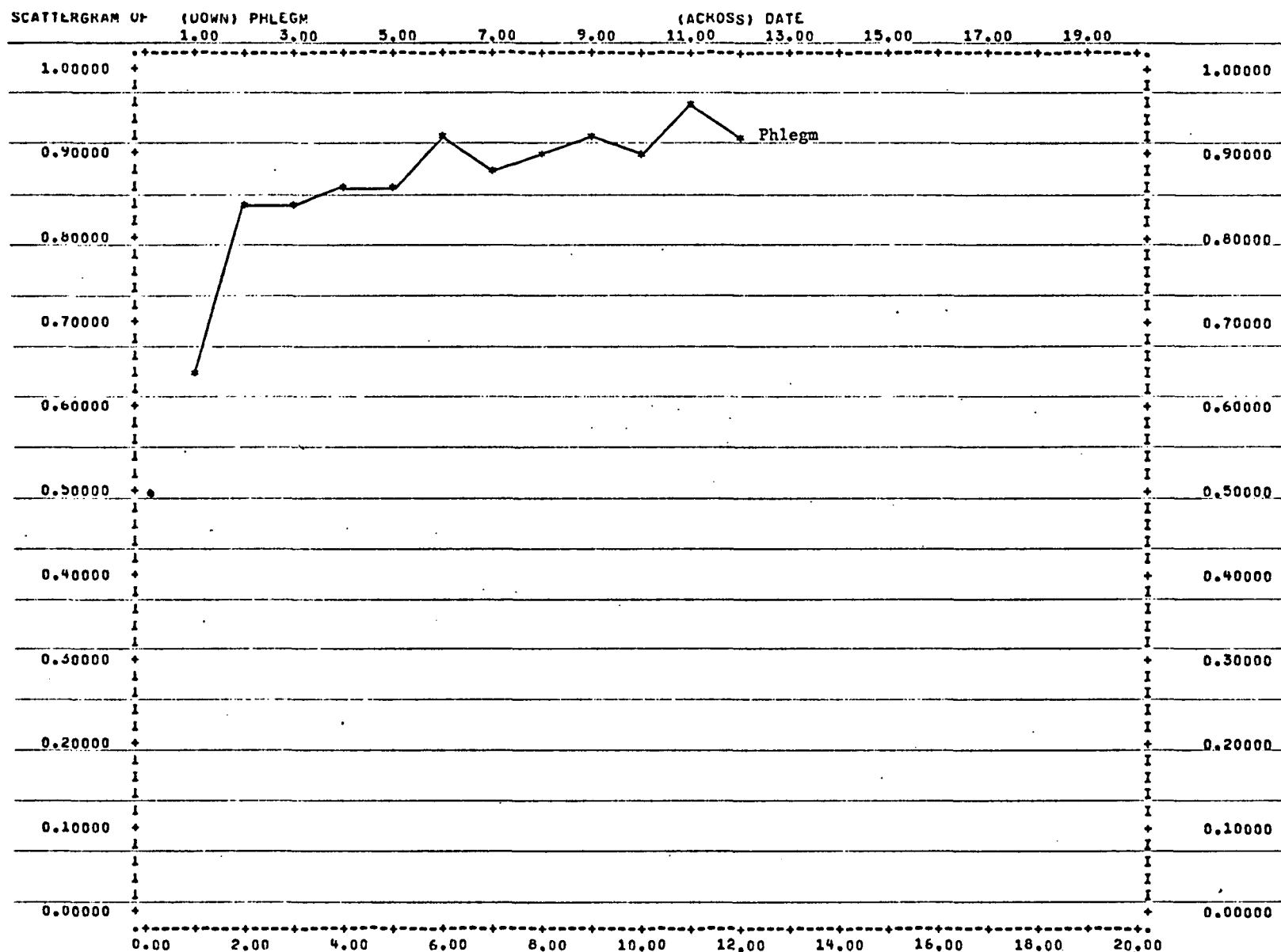
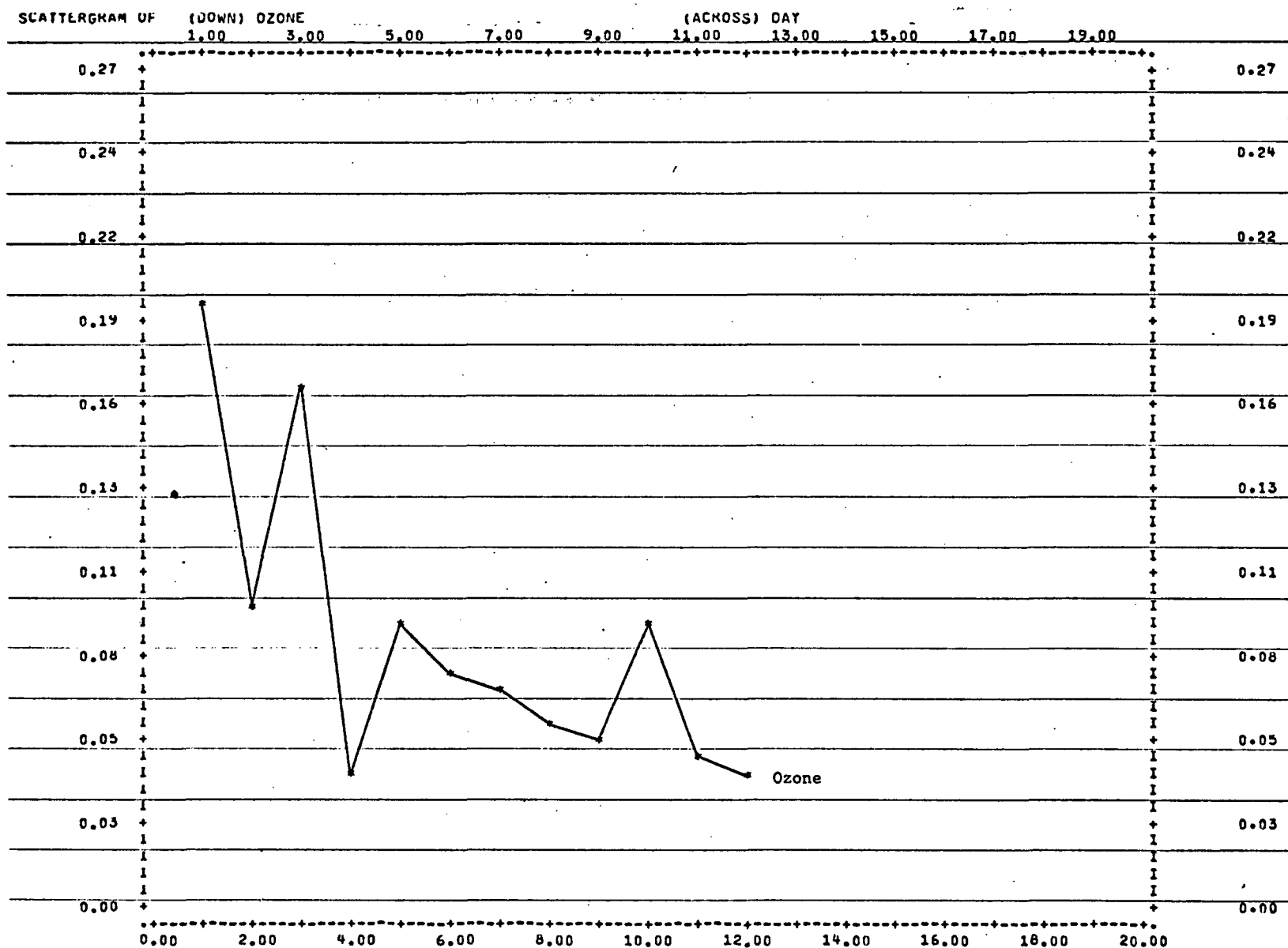Figure K-9.   Proportion of bronchitis panel reporting phlegm by date.

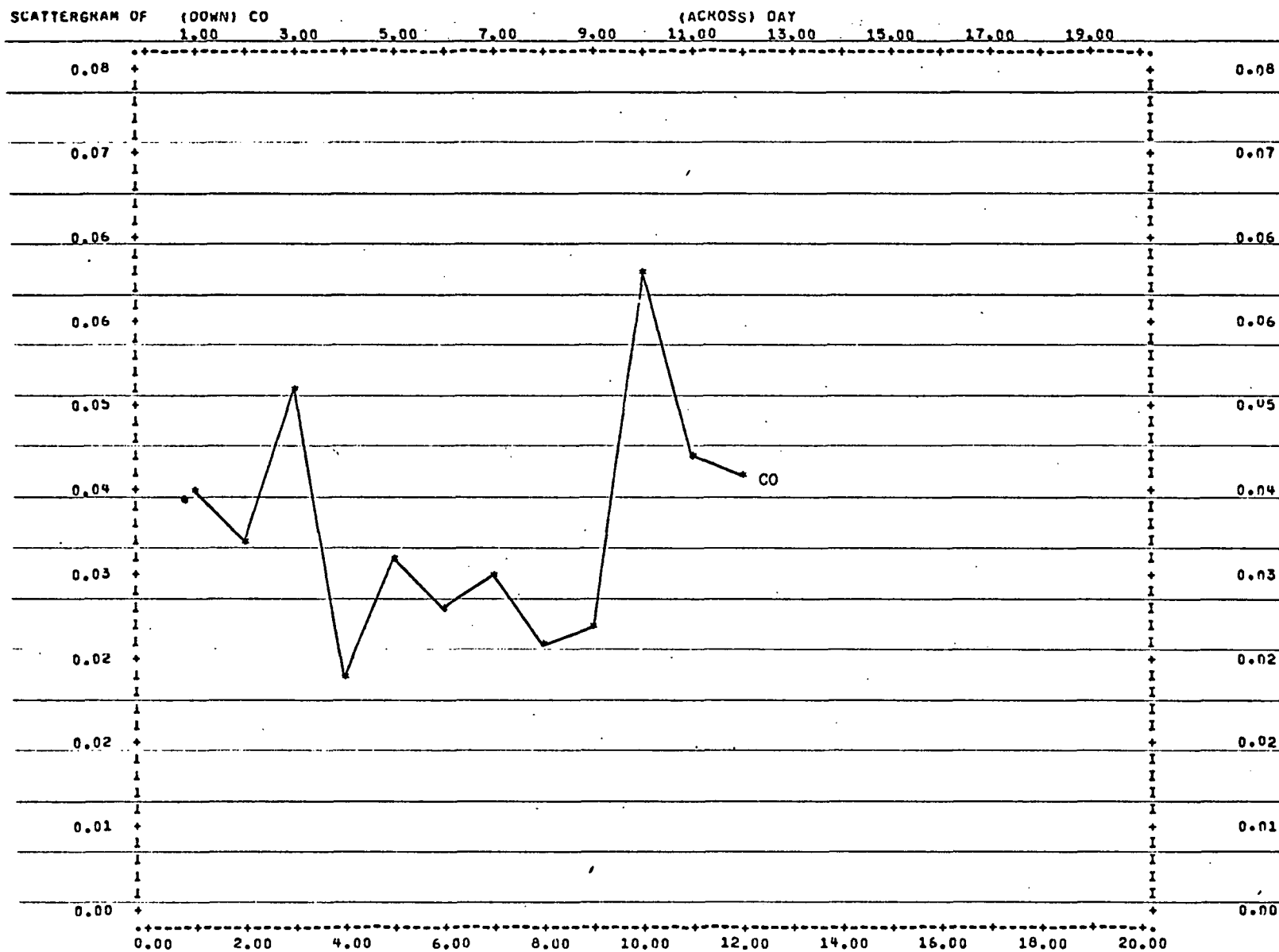Figure K-10. Average level of ozone by date: bronchitis panel.

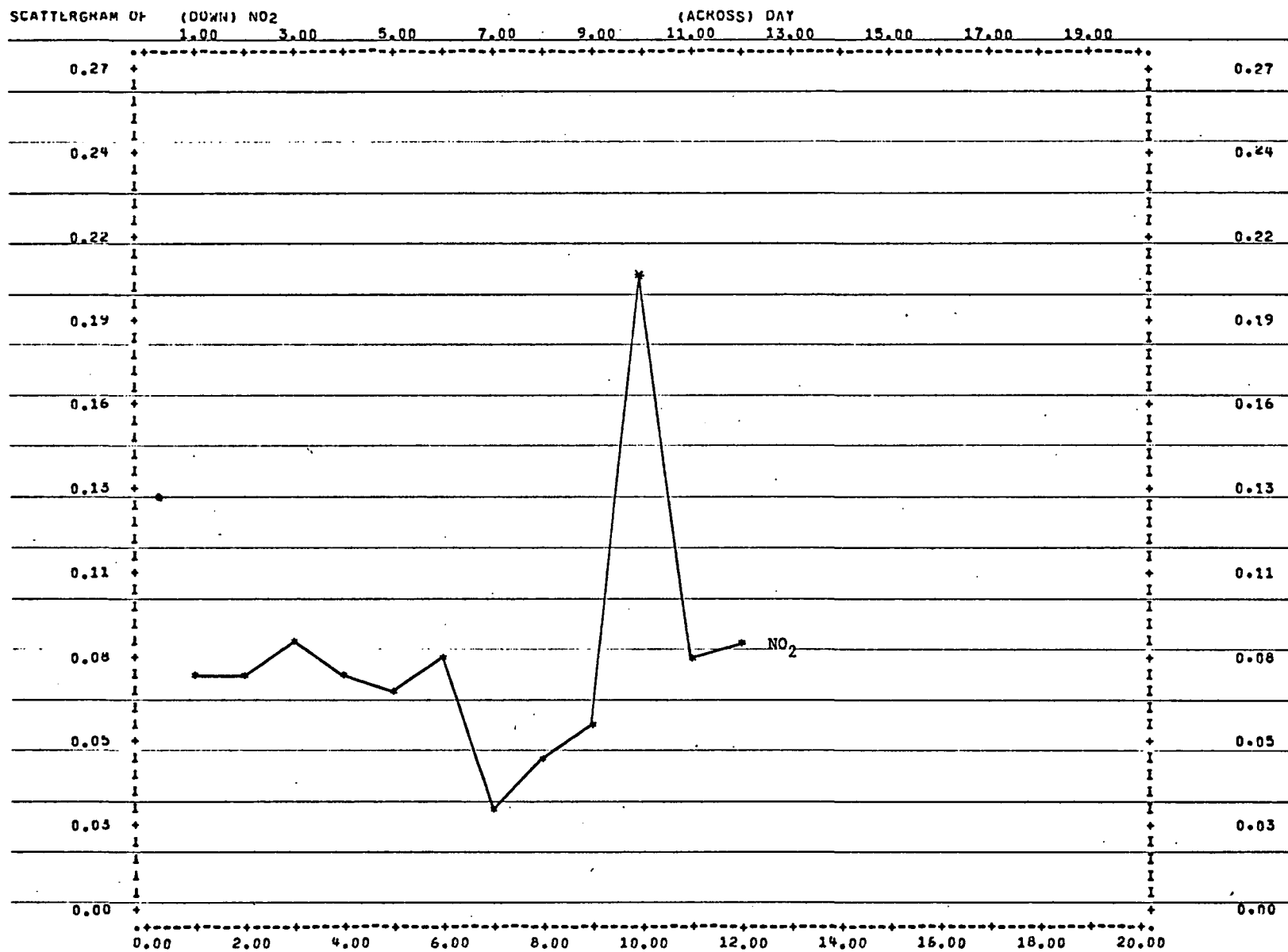Figure K-11.   Average level of carbon monoxide by date: bronchitis panel.

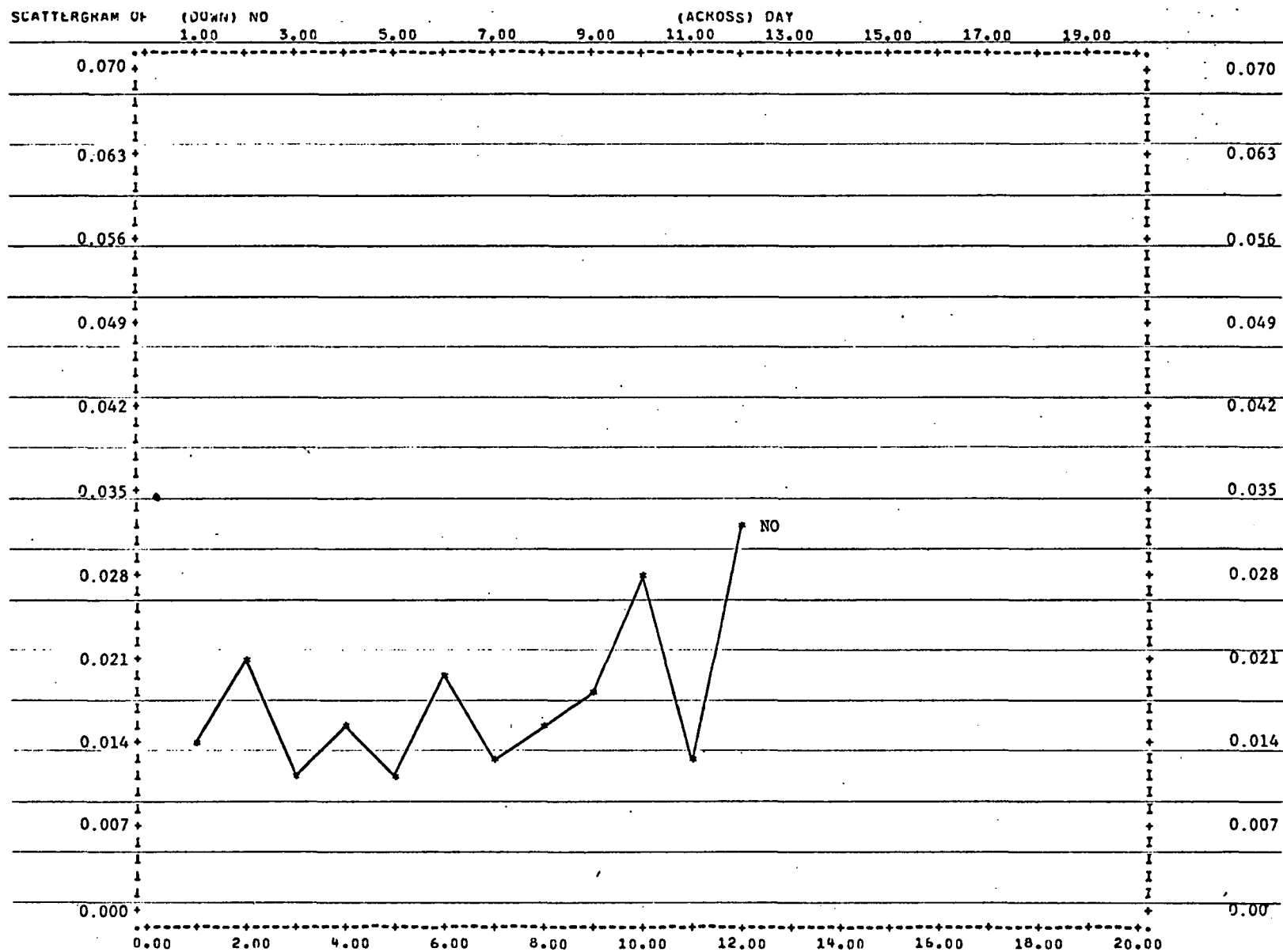Figure K-12.   Average level of nitrogen dioxide by date: bronchitis panel.

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Figure K-13. Average level of nitric oxides by date: bronchitis panel.
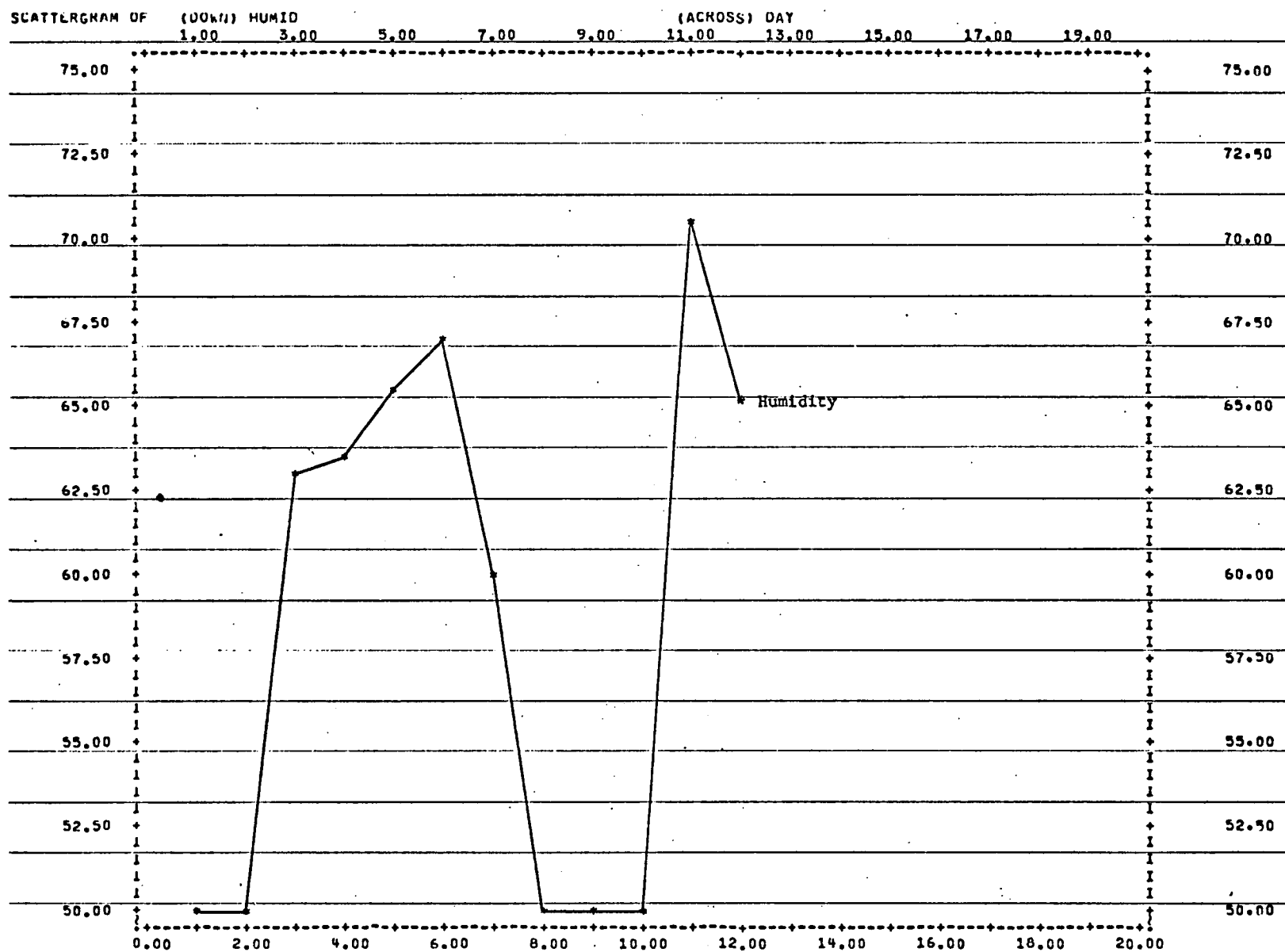
Figure K-14. Average relative humidity by date: bronchitis panel.

SCATTERGRAM OF   (DOWN) TEMP   (ACROSS) DAY
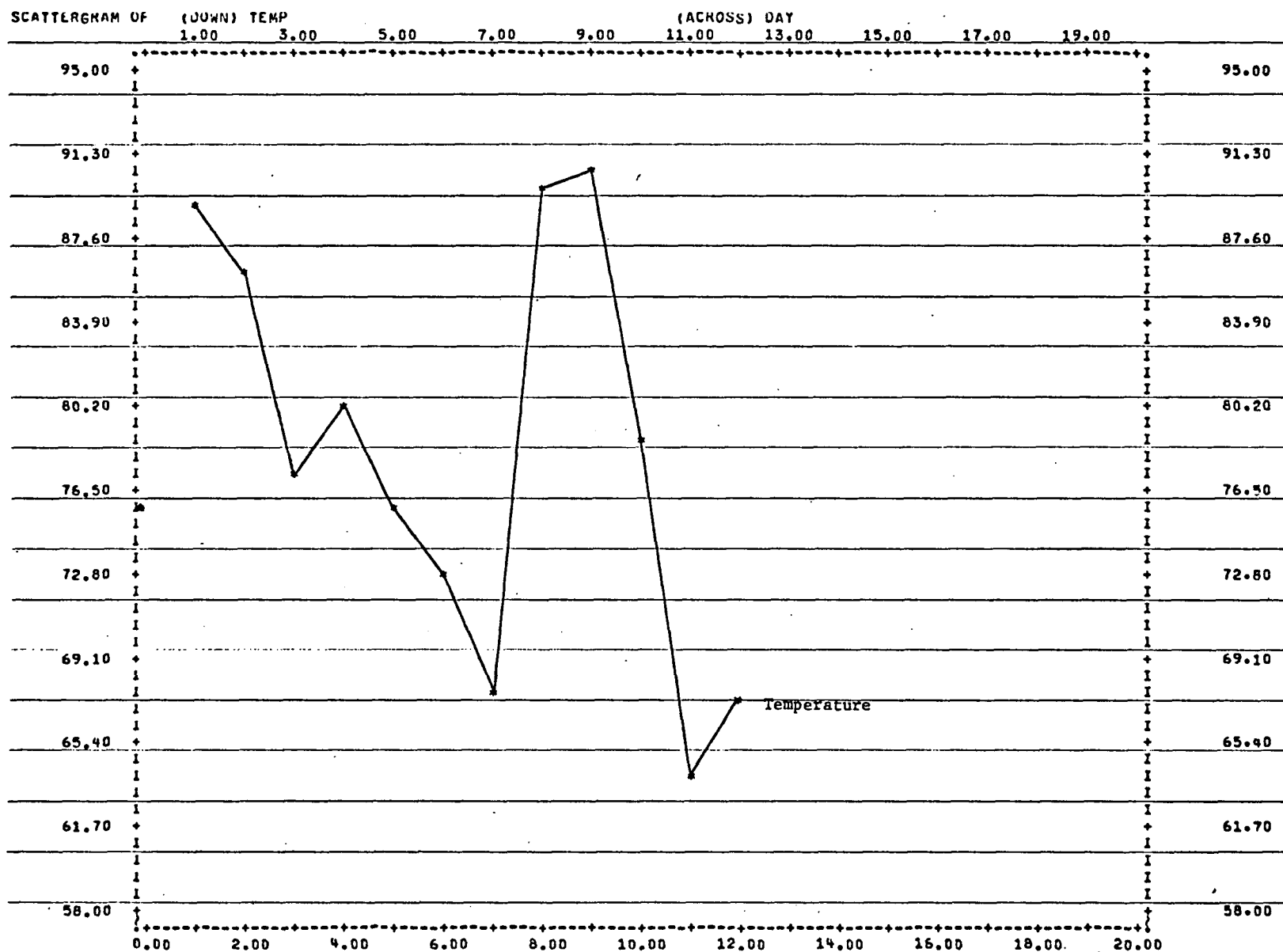
Figure K-15.   Average temperature by date: bronchitis panel.

APPENDIX L

ATHLETE PANEL DATA COLLECTION SCHEDULE

ATHLETE PANEL DATA COLLECTION SCHEDULE

Discomfort symptoms and aerometric data were collected from members of the athlete panel on the dates shown below. This was during late summer and fall of 1974.

Day Number	Date
1	September 9
2	10
3	12
4	19
5	October 3
6	10
7	17
8	24
9	26
10	29
11	November 6