OZONE-HEALTH EFFECTS FIELD STUDY OF CHILDREN AND COUNSELORS AT TWO DAY CAMPS IN NEW JERSEY, JULY 1988

JULY 1990

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NEW JERSEY DEPARTMENT OF HEALTH
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EXECUTIVE SUMMARY

In the summer of 1988 a field study of ozone health effects was conducted at two summer day camps in suburban-central New Jersey. Respiratory health effects of exposures to daily outdoor ambient levels of ozone were evaluated. This was accomplished by assessing the daily pulmonary function, as measured by spirometry, of a group of outdoor employees and summer day camp children. The study was a cooperative effort between the New Jersey Department of Health (NJDOH), the University of Medicine and Dentistry of New Jersey (UMDNJ) - Robert Wood Johnson Medical School, and the New Jersey Department of Environmental Protection (NJDEP).

The objectives of the study were to: 1) evaluate community exposures to ozone in an outdoor setting; 2) attempt to document health effects to outdoor workers and children; and 3) use this information to develop a rationale for policy setting in the area of ozone risk communication and community outreach.

Thirty-four campers and counselors had daily pulmonary function tests performed each afternoon while attending camp during the month of July. The subjects ranged from 9 to 35 years of age and were evenly divided among males and females. Twenty subjects were of ages 14 and over. The 14 children under age 14 were day campers and attended the same camp. A mobile medical screening van was used to house the spirometric equipment and travel to each camp. Continuous ozone measurements were collected at two locations over the entire study period by the NJDEP.

The summer of 1988 experienced some of the worst episodes of ozone air pollution in recent history with recorded high ozone levels during most of the summer. An intense ozone episode was recorded just prior to and during the first two weeks of the study.

A respiratory symptom questionnaire and activity timeline log were administered to the subjects daily. Symptoms surveyed include scratchy throat, cough, hoarseness, phlegm, wheezing, runny or stuffy nose, eye irritation, shortness of breath, and headache. The most commonly reported symptoms for all subjects were phlegm production and runny or stuffy nose. Most positive responses catergorized the symptom severity as mild. The prevalence of reported symptoms in children was greater on high ozone days than on low ozone days.

Consistent with previous observations, the current study demonstrated an impact of outdoor ozone levels on peak expiratory flow rates in children. The eight-hour ozone exposure measure showed the strongest relationship between peak flow decrements and ambient ozone levels. Children demonstrated an average loss of between 2.35 and 4.74 ml/sec/ppb. This equates to an average peak flow loss in children of 8.4 percent for each 100 ppb increase in ozone concentration. Thus, childhood peak flow rates appear to provide the most sensitive indicator of ozone response.

No statistically significant relationship was observed for other lung function measures in children. Nor was there a detectable ozone-pulmonary function response relationship for the counselors. One plausible explanation for the lack of statistically significant slopes in this study is the impact of cumulative daily exposures to ambient ozone on the participants. There is evidence from other camp studies that a persistent shift in baseline respiratory function occurs following an ozone episode. In this study, the initial ozone episode was larger and much more severe than earlier studies. A major portion of the low individual peak flow rates occurred after the conclusion of the ozone episode. It appears that the presence of an extended ozone episode during the first two weeks of study affected the daily dose-response relationship.

Primary prevention to ozone exposure through decreased ambient levels is the best method for protecting public health. However, it is likely that summer-time ozone levels will remain high for the foreseeable future due to the enormous complexity of the problem. Given this, the only visible public health alternative is to increase the public's awareness (i.e., secondary prevention) of the potential ozone-related health hazards and what can be done on a personal level to reduce those hazards through changing individual behaviors, such as modification of activity levels during ozone episodes.

For the past few years, NJDOH and NJDEP have been actively working together to inform the public about ozone episodes, the hazards of ozone exposure and how to reduce overall individual risks. Activities such as the NJDEP Ozone Advisory System (Episode Watch), the NJDOH identification and dissemination of information to high risk groups, and active deparmental participation with environmental and educational organizations need to be continued. New Jersey must continue its commitment and efforts to reduce ozone formation as well as to address other significant outdoor air pollution issues that affect public health.

INTRODUCTION

Ozone is a persistent summertime air pollutant in New Jersey (USEPA, 1990; Berry and Klotz, 1987). Frequent violations of the National Ambient Air Quality Standard occur each year with numerous multiple day episodes and multiple hour daily elevations. The purpose of the present study was to evaluate the respiratory health effects of outdoor occupational and community exposures to ambient ozone. This was accomplished by assessing the daily pulmonary function, as measured by spirometry, of a group of outdoor employees at two day camps during the summer. For comparison, a subset of children (day campers) participating in one of the day camps was included in the overall study design. The findings presented here have important implications for state governmental policy concerning the control of occupational and community exposures to ambient ozone and risk communication policy targeted to high risk groups. The study was a joint cooperative effort between the New Jersey Department of Health (NJDOH), the University of Medicine and Dentistry of New Jersey (UMDNJ) - Robert Wood Johnson Medical School, and the New Jersey Department of Environmental Protection (NJDEP).

A number of controlled human exposure chamber studies have reported significant decrements in pulmonary function, and the presence of respiratory symptoms, associated with ozone exposure. The majority of the controlled chamber studies have focused on the effects of ozone alone among exercising adults. As the ozone-health effects literature grows, there is strong evidence that lung function decrements can occur at relatively low ozone concentrations. Laboratory and field studies of adults who exercise heavily for short periods of time have provided evidence for the existence of short-term, reversible decrements in pulmonary function to ozone concentrations at or near the National Ambient Air Quality Standard of 0.12

parts per million (ppm) (McDonnell et al., 1983; Adams and Schelegle, 1983; Kulle et al., 1985; Spektor et al., 1988a; Avol et al., 1984, 1985). A controlled chamber study of children exposed to low levels of ozone while vigorously exercising also demonstrated significant decreases in pulmonary function (McDonnell et al., 1985).

The duration of ozone exposure in many chamber studies has been one to two hours. As noted, lung function decrements have been reported following short-term exposures to relatively low concentrations of ozone. Lung function decrements are also a function of exposure duration. Since elevated ambient ozone episodes frequently last many hours, prolonged exposure to ozone levels above the national health standard are of significant public health concern. One chamber study (Folinsbee et al., 1988) recently reported on adults who were exercising moderately while being exposed to 0.12 ppm ozone for 6.6 hours. The authors concluded that prolonged exposure resulted in progressive and significant changes in respiratory function and symptoms.

Epidemiological evaluation of children playing outdoors has offered a unique opportunity to explore the human responses to ambient levels of ozone in a natural setting. During the summer, children typically spend much of their time outdoors engaged in supervised or unsupervised recreational activities, which are frequently very active. The long hours children spend outdoors generally occur at a time of day when ambient ozone concentrations are typically at their highest. Furthermore, children have a higher respiratory rate than adults. All of these factors would increase children's effective ozone dose to the lungs.

Field health studies of children attending summer camps in California, Pennsylvania and New Jersey have detected inverse associations between lung function and maximum hourly ozone concentrations measured outdoors (Lippmann et al., 1983; Bock et al., 1985; Lioy et al., 1985; Spektor et al., 1988a; Higgins et al., 1990). In two of these studies, all maximum hourly ozone concentrations were below the current National Ambient Air Quality Standard (NAAQS). Another study of children in Tennessee (Kinney et al., 1989) detected decreases in pulmonary function with a maximum hourly ozone concentration of 0.078 ppm, well below the NAAQS.

A study of adults engaged in a regular daily program of outdoor exercise in New York State found significant decrements in pulmonary function (Spektor et al., 1988b). The decrements were similar in magnitude to those seen in children in summer camp and about twice as large as those reported for chamber studies. The authors concluded that ambient cofactors can increase ozone responsiveness and that the results from chamber studies may substantially underestimate the ozone associated effects that can occur among populations engaged in normal outdoor recreational activity.

Of further concern is the fact that two studies (Lioy et al., 1985; Raizenne et al., 1989) have shown that baseline shifts in pulmonary function parameters can occur after pollution episodes. This produces complications in interpreting ozone exposure-pulmonary response data from day to day, and indicates additional biological responses can occur in the lung.

Pulmonary responses resulting from exposure to levels of ozone below the health standard have been documented in healthy active children and adults. The ozone levels at which these effects have occurred are commonly found in New Jersey during the summer months. The objectives of this study were to: 1) evaluate community exposures to ozone in an outdoor suburban setting; 2) attempt to document pulmonary responses and symptom expression in outdoor workers and children; and 3) use this information to develop a rationale for policy setting in the area of ozone risk communication and community outreach.

METHODS

Collection of Exposure Monitoring Data:

Two ambient air pollution monitoring sites were used for the study. One was an existing regional monitoring station operated by NJDEP and located at Rider College in Lawrence Township, Mercer County, within eight miles of the participating camps. The other monitoring site was a mobile trailer located on site at the Hamilton YMCA, one of the two day camps in the study. The mobile trailer monitor was installed and operated specifically for this study by NJDEP. Ozone was continuously monitored using a chemiluminescent analyzer and hourly ozone concentrations were entered into an exposure data base by UMDNJ. Quality assurance for the ozone data was performed by the NJDEP.

An exposure data base was developed from the data collected at each monitoring location. Ozone measures of interest included the one-hour average ozone value just prior to the daily spirometric test and the eight-hour average ozone level for the day of the test, 9 A.M. to 4 P.M. In order to take into account cumulative ozone exposures over multiple days, two additional ozone metrics were calculated. These include two- and three-day running averages using the daytime eight-hour average ozone level (9 A.M. to 4 P.M.) for the test day, the day prior to the test, and two days prior to the spirometry test.

Ambient temperature, relative humidity, wind rose, precipitation, and UV radiation were provided by Princeton University Center for Energy and Environmental Studies.

Study Period and Population:

In New Jersey, the month of July consistently has the highest magnitude and frequency of ozone episodes (Berry and Klotz, 1987). For this reason, the month of July was selected as the study period. Data were collected Monday through Sunday for the month of July 1988, beginning on Tuesday, July 5th. Since the participants only attended day camps, each subject could have up to 19 test days.

Two central suburban New Jersey summer day camps were chosen for study. Both camps were located in Mercer County. They were approximately two miles apart. The day camps included a private camp, the Hamilton YMCA (Y-camp), and a camp run by a municipal recreation department, the Hamilton Recreation Day Camp (Rec-camp). A total of thirty-four subjects were enrolled in the study: 20 counselors and 14 campers. The camps were visited at the same time of day throughout the study period by a NJDOH mobile medical van.

A pre-questionnaire was administered to all subjects in May or June to ascertain their baseline health status and to provide a basis for evaluation for eligibility into the study. The questionnaire was adapted from the Harvard health questionnaire for the pre-health status evaluation (Speizer, 1988). Individuals with pre-existing respiratory disease (eg., asthma) were excluded from the study.

Collection of Health Data:

Daily Symptom Questionnaire and Activity Log

A daily symptom questionnaire and a brief daily activity log were developed for use during the testing program. The daily questionnaire was administered by a trained nursing staff and was based on self-reporting of symptoms and activity for the previous 24-hour period. Symptoms surveyed include scratchy throat, cough, hoarseness, phlegm, wheezing, runny or stuffy nose, eye irritation, shortness of breath, and headache. Symptom severity was specified to be absent, mild, moderate, or severe. Subjects were also asked about bronchodilator or inhalant use, daily smoking history, and exposure to secondary smoke.

In order to consider the effect of physical exertion on the effects of ozone upon the respiratory tract, a daily activity time log was developed to ascertain activity, location of activity, and the level of exertion of the activity for each subject. Level of exertion was self-reported as mild, moderate, strenuous, or maximal.

Preliminary information collected on each subject during the first day of testing included age, race, sex, weight, height, residential address, and camp attended. Standing height was measured without shoes.

Pulmonary Function Testing

The pulmonary function tests were administered at the Y-camp on 19 days and, due to scheduling differences, only on 12 days at the Rec-camp. None of the participants were available for testing on the weekend. The testing was done by trained technicians using a calibrated Collins water seal spirometer equipped with an Eagle I microprocessor which provided an immediate printout of pre-selected spirometric indices. The spirometer volume was calibrated daily using a standard three-liter syringe to insure that an accuracy of +/- three percent of the reading was maintained. The spirometer was transported between the camps in an air conditioned, mobile medical van. Ambient temperature was measured at each test site.

Three measures of lung function were used: forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), and peak expiratory flow rate (PEFR). The FVC is defined as the largest volume of air that can be forcefully exhaled after a maximal inspiration. The FEV1 is the largest volume of air that can be forcefully exhaled during the first second of the FVC. The highest flow of air that can be exhaled during a forced expiration starting from full inflation of the lungs (i.e., total lung capacity) is called the PEFR.

Each subject performed spirometric maneuvers in a standing position. Subjects wore noseclips. For the days available at both camps, each subject was tested and three acceptable forced maximal expiratory curves were obtained by time-volume tracings. Tracings were considered acceptable if: 1) the rise time of the curve was smooth and free from evidence of variable effort or coughs, displaying no bumps or deflections in the tracings; 2) no early terminations occurred (failure to reach a plateau); and 3) the difference between the two best curves was less than five percent or 100 milliliter (ml), whichever is greater. A random sample of ten percent of all spirometric curve tracings were evaluated by a certified respiratory technician to determine the presence of quality assurance criteria as defined by the American Thoracic Society (ATS) standards (ATS, 1987).

The NJDOH medical van visited each camp between the hours of noon and 5 P.M. The Rec-camp was visited first each day and respiratory testing occurred between 12:00 noon and 1:30 P.M. The Y-camp lung function testing occurred between 3:30 P.M. and 4:30 P.M. on each day of the study.

Analysis of Lung Function Data:

From the three best tracings made by each subject each day, lung function (FVC, FEV1, and PEFR) values were calculated using criteria established by the ATS Snowbird Workshop (Gardner et al., 1979). Two different sets of analyses were performed on the data: individual linear regression for each subject and daily average measures for all subjects and particular sub-groups.

The first set of analyses included all subjects who underwent spirometric testing during the four-week study. Individual linear regression slopes were computed for each subject's lung function versus ozone exposure in the one-hour and four- or eight-hour period preceding the lung function measurement. A four-hour average ozone exposure metric was used for the

Rec-camp and an eight-hour average for the Y-camp since testing was completed earlier in the day for the Rec-camp and later for the Y-camp. Linear regression slopes for the lung function values versus ambient temperature were also computed.

The individual regression slopes were averaged together and tested for statistical significance using T-tests. The average regression slopes were then expressed in terms of milliliters per parts per billion (ml/ppb) ozone for FVC and FEV1 and milliliters per second per parts per billion (ml/sec/ppb) ozone for PEFR. The data set was examined for statistical outliers, defined as individual data points lying at least three standard deviations from the ozone versus function regression lines for each subject.

The data were analyzed further by comparing the observed peak expiratory flow rates for each subject with the expected peak flow rates based on each subject's age, sex, and height. Expected peak flows were calculated from Knudson's predicted equations (Knudson et al., 1976). Two daily summary measures were calculated for peak flows. The first measure was the average daily <u>difference</u> between the individual's observed minus expected peak flow. The average difference regression line slopes were determined and expressed in terms of ml/sec/ppb. The second measure was the average daily <u>ratio</u> of each subject's observed to the expected function level. The average ratio regression line slopes were expressed in terms of percent change per ppb. Linear regression slopes were calculated for each daily summary measure and the ozone exposure in the one-hour and eight-hour period preceding the spirometric test. Additionally, two- and three-day running ozone averages using the daily eight-hour average from the day of the lung function exam and up to two days prior to the examination were used as exposure metrics.

RESULTS

Exposure Monitoring Data:

The summer of 1988 experienced some of the worst episodes of ozone pollution in recent history (Lioy et al., 1989), and New Jersey recorded high ozone levels during most of the summer. The camp locations experienced two distinct ozone episodes during the study. The first episode began two days prior to the start of the study and was marked by a persistent elevated peak ozone level near or above the NAAQS for approximately two weeks. High ozone levels persisted until the beginning of the third week of the study. Ozone levels were relatively low to moderate for the third week due to rainy and/or cloudy weather. The second ozone episode occurred during the last week of the study. These sharp differences in ozone levels provided an opportunity to examine the effects of persistent versus daily ozone exposure on lung function; however, it precluded obtaining the baseline lung function data on each participant, which was obtained in the previous studies by Lippmann et al. (1983) and Spektor et al. (1988). Further, since the testing ended on July 29th, there were an inadequate number of days available after the episode periods to establish the baseline as reported by Lioy et al. (1985).

The Rider College monitoring site recorded eight days in July (25.8%) with at least one daily one-hour peak ozone concentration above the ambient air quality standard of 0.12 ppm. The Rider College maximum one-hour peak ozone level reached 0.204 ppm during one of the days of the study period.

Due to electrical problems during the installation and early operation of the Hamilton ozone monitoring equipment at the Y-camp, ozone data were not available from that location until the last week of the study. The Y-camp ozone monitor was left in operation for one month after the completion of the pulmonary testing. Correlation of ambient ozone measurement was made between the two monitoring sites to ensure that ozone exposures were accurately reflected in the Rider collection site data. Measurements from the two sites were correlated with a regression coefficient of 0.90 (Lioy et al., 1989). Based on the high degree of correlation and closeness of the monitoring site to the camps, the Rider College data were used for analysis.

Figure 1 presents a graph of the early and late afternoon one-hour average ozone levels used as a general exposure metric for the camps in the study (Lioy et al., 1989). The measurements used for a participant were associated with the period just prior to his/her lung function test.

Study Demographics:

A combined total of 34 subjects from both camps participated in the summer study. Table 1 presents the age-sex characteristics of the study population. Of the total, there were 20 persons aged 14 and over, and 14 persons under the age of 14. All of the children under age 14 were day campers and attended the Y-camp. Of the counselors, all aged 14 and over, ten were from the Rec-camp and ten from the Y-camp. Seventeen of the subjects were male and 17 were female. Two counselors from the Y-camp were Afro-American and the remainder of the subjects were Caucasian. The age of the study population ranged from 9 to 35. The mean age of the Rec-camp participants was 17.7 years with a standard deviation of 2.6 years. The mean age of the Y-camp participants was 14.8 years with a standard deviation of 5.9 years. Twenty-three of the subjects lived in the Township of Hamilton, Mercer County. The remainder resided within 15 miles of the camp locations. This made the Rider College data representative of the possible outdoor exposures that occurred during times away from camp.

Daily Symptom Questionnaire and Activity Log:

The two camps differed markedly in their daily operations. The

Rec-camp's hours of operation were 9 A.M. until 2:30 P.M., whereas the Y-camp operated from 8 A.M. until 4:30 P.M. Observation of the two camps' daily activities revealed that counselors and campers at the Y-camp were much more active than the other group. Y-camp subjects reported physical activity more often and for longer periods of time. The measure of physical activity developed for this study is the action level which is based on a person's degree of physical effort and the duration of activities for a given day. The higher action levels of the Y-camp participants are described in Tables 2 and 3.

The pulmonary function tests were administered in the late afternoon at the Y-camp, when ozone levels were generally high. Testing was done at the Rec-camp in the early afternoon. Because of this and the longer duration of exposure and increased activity of the Y-camp, the Y-camp subjects received a larger dose of ozone than those at the Rec-camp (Lioy et al., 1989). Because of this apparent exposure difference between counselors at the two camps, subsequent analyses stratified the counselors by camp attended.

A wide range of responses were evident among the symptom questions. The most commonly reported symptoms for all subjects by person-day were phlegm production (24.6%) and runny or stuffy nose (37.2%). The least reported symptoms included wheezing (2.6%), shortness of breath (4.4%), and chest pains (3.2%). Most positive responses categorized the symptom severity as mild. Few severe responses were reported.

Figure 2 presents the proportion of positive responses on any of the study days by symptom and subject group. The prevalence of reported symptoms was greater for every symptom category among the two Y-camp groups, counselors and campers, than for the Rec-camp group. Runny or stuffy nose occurred in over 50 percent of the person-days for campers at the Y-camp, 72 percent higher than the Y-camp counselors and over two and one-half times more prevalent than the Rec-camp group. The positive response to cough and phlegm was about the same for both Y-camp groups and was approximately three times more frequent than the Rec-camp group. Counselors at the Y-camp reported a substantially higher proportion of hoarseness than either of the other groups.

Figures 3 and 4 represent the proportion of positive responses by symptom and by each Y-camp group for three exposure categories of ozone. Categorization of the exposure variable was done using the hourly ozone concentration just prior to lung function testing. The exposure categories are low (less than 80 parts per billion (ppb)), moderate (80 to 120 ppb), and high (over 120 ppb) ozone. No difference could be detected between the rate of positive symptoms and the ozone level for the Y-camp counselors. For the Y-camp campers, cough and runny or stuffy nose symptoms were related to ozone level. In addition, all camper symptom rates were higher for the highest ozone category than for the lowest category. Since no Rec-camp ozone concentration was over 120 ppb as measured just prior to lung testing, the Rec-camp group was not evaluated for symptoms versus to ozone level.

Pulmonary Function Testing:

Individual Linear Regression

For FEV1, FVC, and PEFR, linear regressions using temperature, the one-hour, or eight-hour ambient ozone concentrations at time of test were calculated for each subject. Negative regression slopes indicate an inverse relationship between lung function and ozone concentration (i.e., decreased pulmonary function with increasing ozone level). The proportion of individuals with negative slopes was greatest among the Y-camp campers for each lung funtion test (Table 4). This relationship was most pronounced for PEFR, with 64% of Y-camp campers demonstrating an inverse relationship between ozone level and peak flow.

The average regression slopes for the three groups and the ambient temperature are presented in Table 5. Three of these regression slopes are negative with only minor decrements. Table 6 shows the average regression slopes for the three groups and the two ozone averages. Four of the regression slopes were negative. The only negative average slope for the one-hour ozone measure was for the Y-camp children: PEFR had an average decrement of 1.01 ml/sec/ppb of ozone. The PEFR decrements in Y-camp children for the eight-hour ozone average concentration displayed the strongest relationship to exposure with an average loss of peak flow per child of 2.35 ml/sec/ppb of ozone.

Daily Average Summary Ratio and Difference Analysis

The regression slopes are presented in Table 7 by study group for the daily average difference of the observed and expected PEFR and four ozone exposure measures: one-hour average, test day eight-hour average, two-day eight-hour average, and the three-day eight-hour average. Very little pattern can be observed in either worker group. A slight decrease in peak flow rates was noticable for the Y-camp counselors for the two- and three-day ozone averages. However, the peak flow slopes were negative for all ozone exposure measures for the Y-camp children. The largest decrement for the average <u>difference</u> of the observed and expected PEFR in children was 4.74 ml/sec/ppb of ozone (p-value = 0.05) for the eight-hour ozone average on the day of the lung test.

Similar results were found for the regression slopes by study group for the daily average <u>ratio</u> of the observed to the expected peak flow, Table 8. The Y-camp children's slopes again were all negative with the largest decrement (0.084% per ppb, p-value = 0.06) found for the eight-hour test day ozone average. This represents an average decrease in children's peak flow rates of 8.4% for each 100 ppb ozone concentration increase.

DISCUSSION

The effects of ozone on lung volumes and flow rates are influenced by the effective dose of ozone to the lungs. Ozone exposure is determined by ambient ozone levels, the duration of exposure, and the level of the subject's physical activity. The latter influences the minute ventilation (i.e., the amount of air brought into the lungs in one minute). These variables determine the effective dose that reaches the exposed individual's lungs. However, a wide range of respiratory responsiveness to ozone has been found in healthy subjects (McDonnell et al., 1985).

The month of July 1988 had multiple days with elevated ozone levels. High ozone levels frequently extended through much of the day camps' operating hours. Ozone levels during the study period displayed a wide range of daily maximum one-hour averages, 56 to 204 ppb. The one-hour average ozone concentrations used as indices in the study also showed a broad range from high to low: 124 ppb difference for the Y-camp and 94 ppb difference for the Rec-camp. Furthermore, six days during the study period had eight-hour average ozone concentrations over 100 ppb. The maximum eight-hour average was 131 ppb. The documented exposure values were used to evaluate the relationship between respiratory function and ambient ozone in a group of moderately active outdoor employees and day campers with two similtaneously distinct exposure values.

The present study, unlike other similar studies (Lippmann et al., 1983; Bock et al., 1985; Lioy et al., 1985; Spektor et al., 1988a, 1988b; Kinney et al., 1989; Higgins et al., 1990), did not detect a statistically significant relationship between the average regression slopes for respiratory function indices and the ambient ozone concentration (Tables 5 and 6). Peak flow rates for the Y-camp children appear to be the only parameter with a relationship similar to earlier study results cited above. The eight-hour ozone exposure measure showed the strongest relationship between peak flow decrements and ambient ozone levels. Children demonstrated an average loss of 2.35 ml/sec/ppb ($p < 0.10$). The degree of loss in peak flow for children is consistent with other studies of summer camp children with low to moderate physical activity levels.

The analysis of the summary daily average difference of the observed and expected peak flow rates provided further evidence that decrements in childhood peak flows occurred. These were close to 4.74 ml/sec/ppb per child (p-value = 0.05) for an eight-hour ozone exposure. The ratio of the observed to the expected PEFR indicated an average peak flow loss in children of 8.4 percent for each 100 ppb change in ozone concentration.

A plausible explanation for the lack of statistically significant slopes in the current study is the impact of cumulative daily exposures to ambient ozone on the participants. As noted earlier, the study area experienced an intense ozone episode prior to the beginning of the study that extended through most of the first two weeks of the study period. Additionally, ambient levels of ozone remained high over numerous hours on each day when ozone was above the NAAQS while the campers exhibited an increased frequency of respiratory symptoms on the days with ozone levels above 120 ppb. Ozone levels did not decrease significantly for any length of time until the third week of the study. From other camp studies (Lioy et al., 1985; Spektor et al., 1988; Raizenne et al., 1989) there is evidence that a persistent shift in baseline respiratory function can occur following an ozone episode. In this study the first episode was larger and much more severe than those observed in the previous studies. The baseline shift was observed as a persistent decrease in function that could last up to a week after the end of a period of elevated ozone. The lowest and second lowest PEFR for the Y-camp children and counselors for the entire study is presented in Figure 5 (i.e., two values per subject). Approximately 43 percent of the lowest and second lowest observed peak flow rates for all Y-camp subjects occurred during the third week of the study, suggesting a baseline shift in pulmonary function occurred in the population. In addition, since there were no pre-episode test days and not enough post-episode test days available to establish a baseline function for an individual, the linear relationship of ozone with pulmonary function that has been seen in other studies was obscured by the persistent decrease in lung function for low ozone days that occurred after this intense ozone episode.

Even with the episode, childhood peak flow rates appear to provide a sensitive indicator of ozone response. The average PEFR loss of 4.74 ml/sec/ppb for children in this study is consistent with earlier observations of children attending summer camps with peak flow decrements of 3.0 to 6.7 ml/sec/ppb (Bock et al., 1985; Lioy et al., 1985; Spektor et al., 1988). The daily eight-hour ozone average showed the strongest relationship to peak flow decrements in children and is likely to be a better estimate of daily effective dose for ambient exposures than the shorter one-hour average.

CONCLUSIONS

Consistent with previous observations, the current study did demonstrate a community impact of ozone exposure on the pulmonary function variable, Peak Expiratory Flow Rate, in the children (campers). No statistical relationship was observed for FVC or FEV1. There was no detectable ozone-pulmonary function response relationship for the counselors that participated at either camp. The temperature did not have any association with function parameters measured in both populations. It appears that the presence of an extended ozone episode during the first two weeks of study produced a baseline shift in the lung function of the stuey population, and affected the daily dose-response relationship.

The result for the children did indicate that the PEFR was affected by the potential accumulated dose of ozone for at least eight hours prior to a lung function measurement. Further, the largest lung function decrement for a number of the participants occurred on the days just after the episode which suggests a transient baseline shift in the lung function of members within the population, and is a plausible reason why the daily exposure-response relationship was not as strong as that obtained in other investigations.

Increases in specific respiratory symptoms were reported with increasing ozone concentration in both the children and the counselors. This was especially apparent for children on the days with ozone above 120 ppb, which occurred primarily during the major episode.

RECOMMENDATIONS

Primary prevention to ozone exposure through decreased ambient levels is the best method for protecting public health. However, it is likely that summer-time ozone levels will remain high for the foreseeable future due to the enormous complexity of the regional generation and transport of ozone precursors. Given this, the only visible public health alternative will be increasing the public's awareness of ozone-related health hazards and of what can be done on a personal level to reduce those hazards through changing individual behaviors.

For the past few years, NJDOH and NJDEP have been actively working together to inform the public about ozone episodes, the hazards of ozone exposure, and how to reduce overall individual risks. These activities need to be continued and expanded where necessary and should include:

1. The NJDEP Ozone Advisory System (Episode Watch), initiated in 1987, has been an effective mechanism for the timely dissemination of information on ozone episodes to the general public (Edelstein, 1988). The Episode Watch program should be continued with increased efforts to educate the media, such as pre-ozone season press releases and ozone press packages, to encourage more media coverage and transmission of advisory and health information.

2. The NJDOH should continue to develop informational/educational materials for the general public, health educators, and health care professionals. Increasing the public's and professionals' knowledge concerning the environmental hazards of ozone will empower everyone to make educated decisions concerning their health.

3. The NJDOH should increase efforts to identify high risk groups for targeted delivery of health information to those individuals at greatest risk of ozone exposure and/or consequent health effects.

4. NJDOH and NJDEP should continue working with environmental and educational organizations, such as the Northeast States for Coordinated Air Use Management, UMDNJ, Project: Clean Air, and the Interstate Sanatation Commission, in efforts to reduce ozone formation and to address other outdoor air pollution issues in a coordinated and systematic fashion.

FIGURE 1

ONE-HOUR AVERAGE OZONE EXPOSURE LEVELS
NEW JERSEY DEPARTMENT OF HEALTH OZONE HEALTH EFFECTS STUDY
HAMILTON, NEW JERSEY; JULY 1988

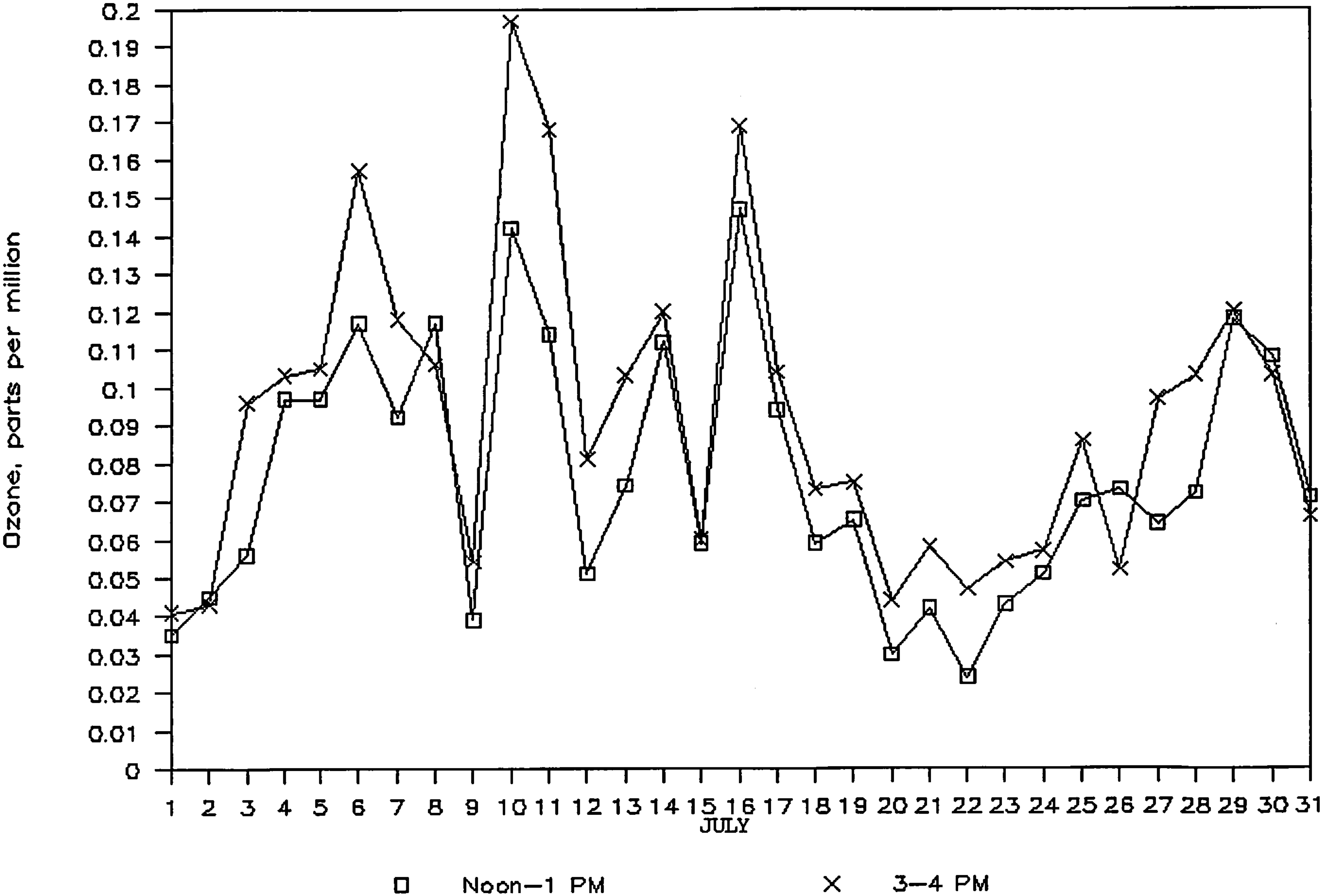


TABLE 1

AGE AND SEX OF SUBJECTS AND PERSON-DAY
TESTS BY SUMMER CAMP ATTENDED
NEW JERSEY DEPARTMENT OF HEALTH OZONE HEALTH EFFECTS STUDY
HAMILTON, NEW JERSEY; JULY 1988

AGE GROUP	SEX	NO. SUBJECTS		NO. PERSON DAYS	
		REC-CAMP	Y-CAMP	REC-CAMP	Y-CAMP
14 AND OVER:					
	MALE	4	4	45	70
	FEMALE	6	6	71	111
	TOTAL	10	10	116	181
UNDER 14:					
	MALE	0	9	0	130
	FEMALE	0	5	0	73
	TOTAL	0	14	0	203
ALL AGES:					
	MALE	4	13	45	200
	FEMALE	6	11	71	184
	TOTAL	10	24	116	384

TABLE 2

ACTION LEVEL ON DAY OF TEST BY GROUP
NEW JERSEY DEPARTMENT OF HEALTH OZONE HEALTH EFFECTS STUDY
HAMILTON, NEW JERSEY; JULY 1988

GROUP	ACTION LEVEL: MINIMAL	MILD	MODERATE	ACTIVE	TOTAL PERSON-
REC-CAMP WORKERS:	22	83	7	4	116
%	19.0%	71.6%	6.0%	3.4%	
Y-CAMP WORKERS:	25	94	38	24	181
%	13.8%	51.9%	21.0%	13.3%	
Y-CAMP CAMPERS:	16	133	47	7	203
%	7.9%	65.5%	23.2%	3.4%	

ACTION LEVEL = SELF-REPORTED ACTIVITY LEVEL TIMES NUMBER OF HOURS.

TABLE 3

AVERAGE ACTION LEVEL ON DAY OF TEST BY GROUP
NEW JERSEY DEPARTMENT OF HEALTH OZONE HEALTH EFFECTS STUDY
HAMILTON, NEW JERSEY; JULY 1988

GROUP	MEAN	STANDARD DEVIATION	PERSON-DAYS
REC-CAMP WORKERS:	0.94	0.62	116
Y-CAMP WORKERS:	1.33	0.88	181
Y-CAMP CAMPERS:	1.22	0.63	203

MINIMAL=0 MILD=1 MODERATE=2 ACTIVE=3

TABLE 4

NUMBER OF INDIVIDUAL REGRESSION SLOPES NEGATIVE FOR RESPIRATORY FUNCTION INDICES VS. ONE-HOUR AMBIENT OZONE LEVEL AT TIME OF TESTING
NEW JERSEY DEPARTMENT OF HEALTH OZONE HEALTH EFFECTS STUDY
HAMILTON, NEW JERSEY; JULY 1988

GROUP	NUMBER OF SUBJECTS	FEV1 NUMBER (%) NEGATIVE	FVC NUMBER (%) NEGATIVE	PEFR NUMBER (%) NEGATIVE
REC-CAMP WORKERS:	10	3 (30%)	2 (20%)	3 (30%)
Y-CAMP WORKERS:	10	3 (30%)	1 (10%)	4 (40%)
Y-CAMP CAMPERS:	14	5 (36%)	3 (21%)	9 (64%)

TABLE 5

AVERAGE REGRESSION SLOPES FOR RESPIRATORY FUNCTION INDICES VS. AMBIENT TEMPERATURE AT TIME OF TESTING
NEW JERSEY DEPARTMENT OF HEALTH OZONE HEALTH EFFECTS STUDY
HAMILTON, NEW JERSEY; JULY 1988

GROUP	NUMBER OF SUBJECTS	FEV1 MEAN (S.E.) ml/ppb	FVC MEAN (S.E.) ml/ppb	PEFR MEAN (S.E.) ml/sec/ppb
REC-CAMP WORKERS:	10	0.001 (0.001)	-0.0001 (0.002)	0.010 (0.010)
Y-CAMP WORKERS:	10	0.002 (0.003)	0.004 (0.002)	-0.008 (0.007)
Y-CAMP CAMPERS:	14	0.004 (0.006)	0.006 (0.002)	-0.006 (0.006)

S.E. = STANDARD ERROR, A MEASURE OF THE PRECISION OF THE MEAN.

FIGURE 2

ANY POSITIVE SYMPTOMS BY PERSON-DAYS
NEW JERSEY DEPARTMENT OF HEALTH OZONE HEALTH EFFECTS STUDY
HAMILTON, NEW JERSEY; JULY 1988

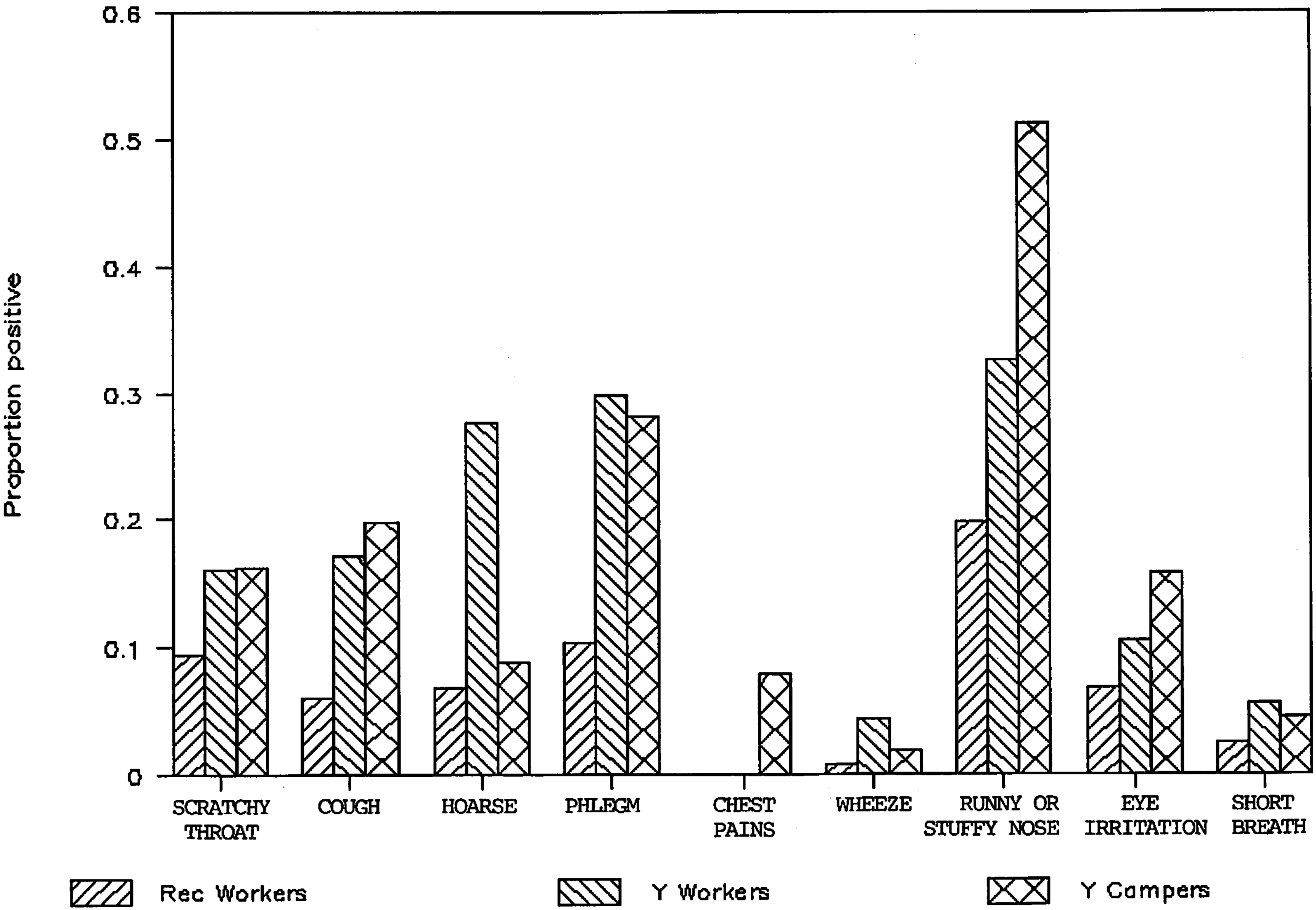


FIGURE 3

Y-CAMP WORKERS' POSITIVE SYMPTOMS BY OZONE LEVEL
NEW JERSEY DEPARTMENT OF HEALTH OZONE HEALTH EFFECTS STUDY
HAMILTON, NEW JERSEY; JULY 1988

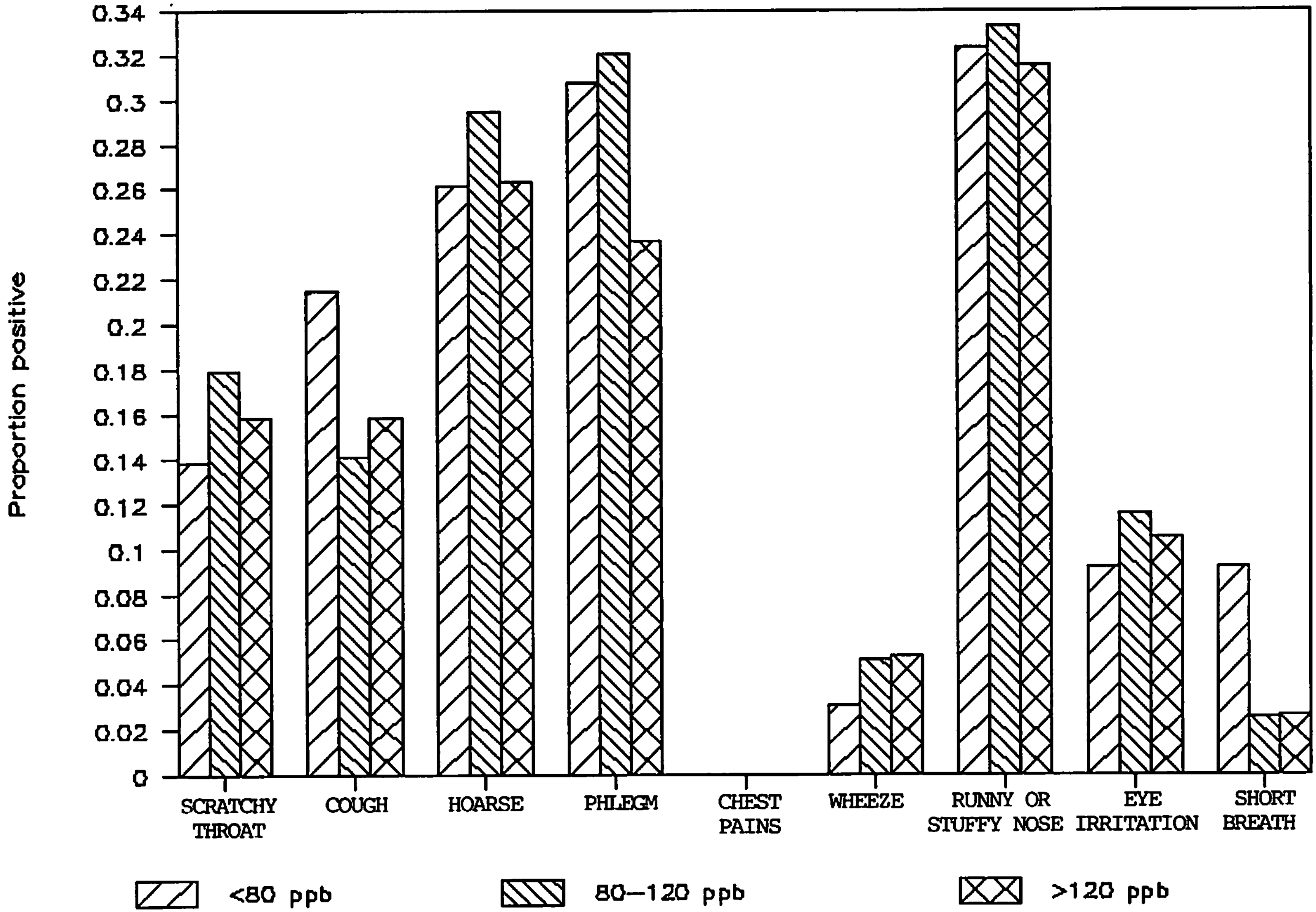


FIGURE 4

Y-CAMP CAMPERS' POSITIVE SYMPTOMS BY OZONE LEVEL
NEW JERSEY DEPARTMENT OF HEALTH OZONE HEALTH EFFECTS STUDY
HAMILTON, NEW JERSEY; JULY 1988

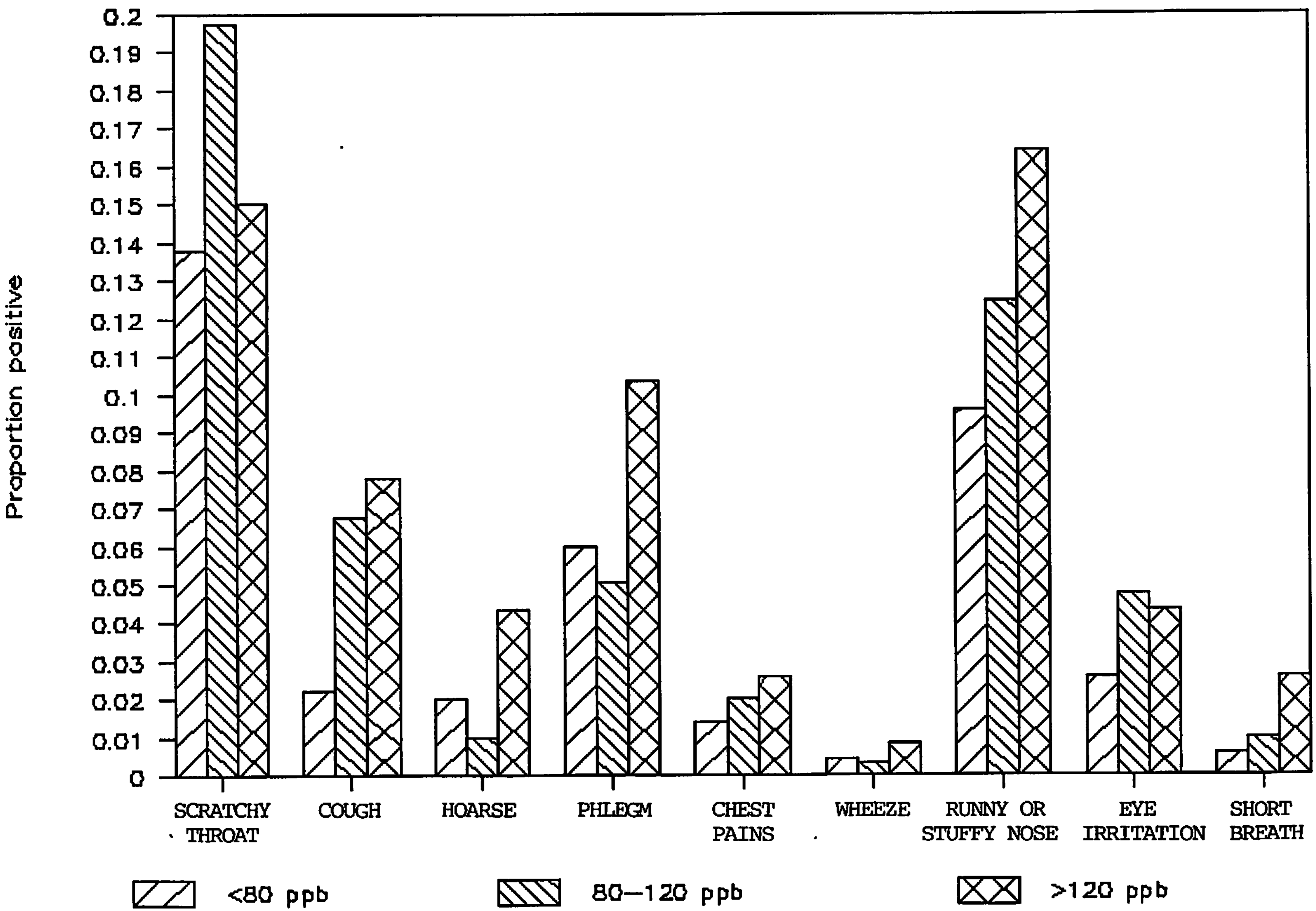


TABLE 6

AVERAGE REGRESSION SLOPES FOR RESPIRATORY FUNCTION INDICES
VS. AMBIENT OZONE LEVELS AT TIME OF TESTING
NEW JERSEY DEPARTMENT OF HEALTH OZONE HEALTH EFFECTS STUDY
HAMILTON, NEW JERSEY; JULY 1988

GROUP	NUMBER OF SUBJECTS	FEV1 MEAN (S.E.) ml/ppb	FVC MEAN (S.E.) ml/ppb	PEFR MEAN (S.E.) ml/sec/ppb
1. ONE-HOUR AVERAGE				
REC-CAMP WORKERS:	10	0.57 (0.36)	0.002 (0.68)	1.63 (2.23)
Y-CAMP WORKERS:	10	0.46 (0.49)	0.84 (0.31)	0.98 (0.98)
Y-CAMP CAMPERS:	14	0.82 (0.33)	0.83 (0.38)	-1.01 (1.17)
2. EIGHT-HOUR AVERAGE				
REC-CAMP WORKERS:	10	0.52 (0.70)	-0.19 (0.78)	0.83 (4.10)
Y-CAMP WORKERS:	10	-0.21 (1.03)	0.27 (0.99)	0.60 (1.23)
Y-CAMP CAMPERS:	14	0.89 (0.42)	1.29 (0.49)	-2.35*(1.44)

* p-value between 0.10 and 0.05, one tailed t-test

Note: 4-hour ozone average used for Rec-camp instead of 8-hour average

S.E. = STANDARD ERROR, a measure of the precision of the mean.

TABLE 7

PEAK EXPIRATORY FLOW RATES
AVERAGE DIFFERENCE OF OBSERVED AND EXPECTED PER DAY
NEW JERSEY DEPARTMENT OF HEALTH OZONE HEALTH EFFECTS STUDY
HAMILTON, NEW JERSEY; JULY 1988

	EXPOSURE ESTIMATES							
	1-Hour Ave		8-Hour Ave		2-Day Ave		3-Day Ave	
GROUP	Slope*	p-value	Slope	p-value	Slope	p-value	Slope	p-value
REC-CAMP:**	3.027	(0.29)	3.029	(0.34)				
Y WORKERS:	0.531	(0.43)	0.344	(0.47)	-1.729	(0.36)	-5.045	(0.35)
Y CAMPERS:	-2.961	(0.10)	-4.740	(0.05)	-3.403	(0.16)	-2.127	(0.30)

* Slope in ml/sec/ppb

** Four-hour ozone average used instead of eight-hour average

Note: p-values are from one tailed t-tests

TABLE 8

PEAK EXPIRATORY FLOW RATES
AVERAGE RATIO OF OBSERVED TO EXPECTED PER DAY
NEW JERSEY DEPARTMENT OF HEALTH OZONE HEALTH EFFECTS STUDY
HAMILTON, NEW JERSEY; JULY 1988

GROUP	EXPOSURE ESTIMATES							
	1-Hour Ave		8-Hour Ave		2-Day Ave		3-Day Ave	
	Slope*	p-value	Slope	p-value	Slope	p-value	Slope	p-value
REC-CAMP:**	0.041%	(0.28)	0.044%	(0.33)				
Y WORKERS:	0.007%	(0.43)	0.005%	(0.46)	-0.020%	(0.37)	-0.068%	(0.35)
Y CAMPERS:	-0.049%	(0.13)	-0.084%	(0.06)	-0.064%	(0.16)	-0.038%	(0.30)

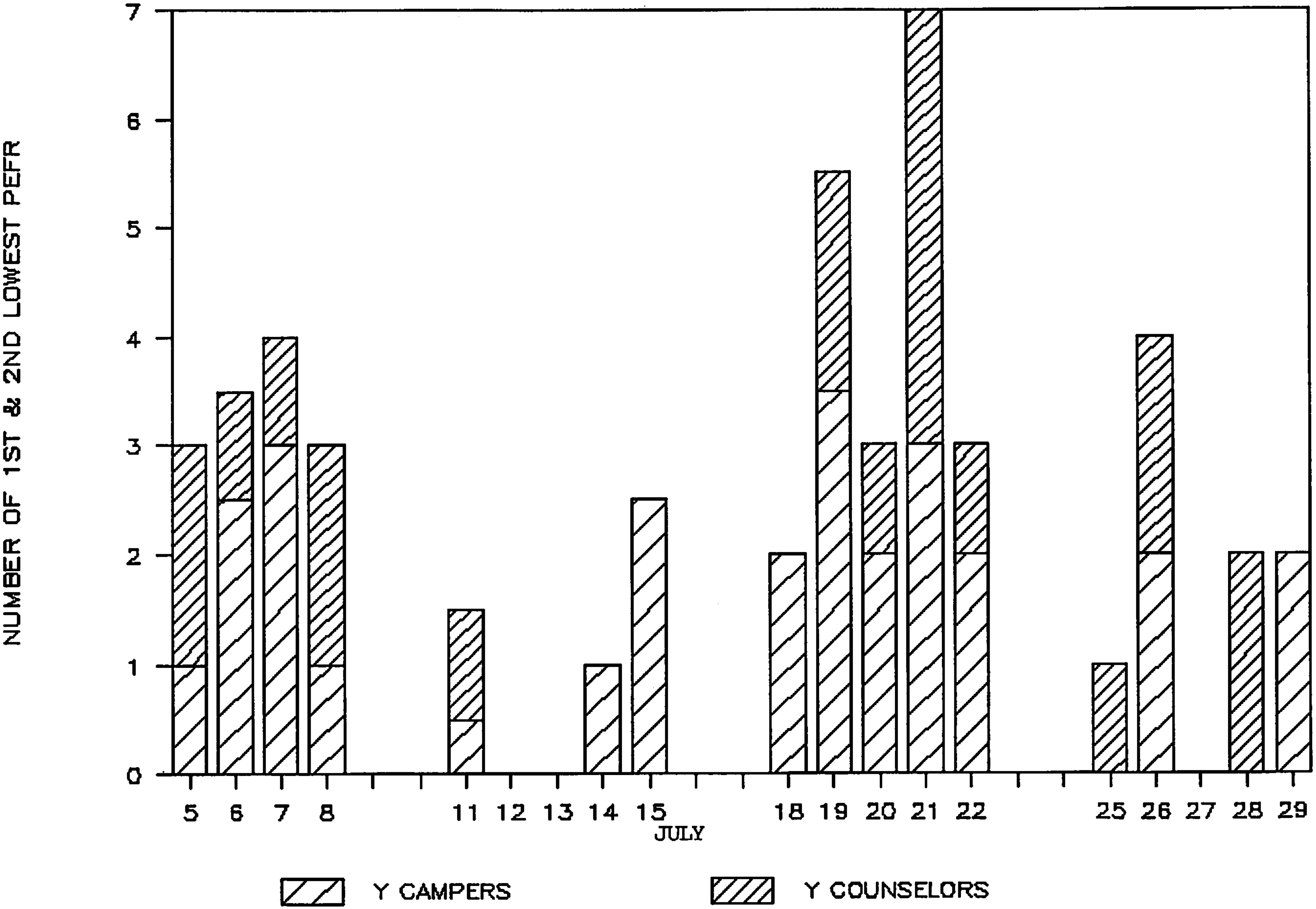
* Slope in percent change per ppb

** Four-hour ozone average used instead of eight-hour average

Note: p-values are from one tailed t-tests

FIGURE 5

Y-CAMP SUBJECTS' LOWEST AND SECOND LOWEST PEFR
NEW JERSEY DEPARTMENT OF HEALTH OZONE HEALTH EFFECTS STUDY
HAMILTON, NEW JERSEY; JULY 1988



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