"CHANGES IN LUNG FUNCTION & EXPOSURE TO OXIDANTS"

Contract Number A0-133-32

<u>Final Report</u>

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Executive Summary

Introduction

Although animal studies strongly suggest that significant physiologic and pathologic lung damage is associated with long-term or repetitive exposure to oxidants, nitrogen dioxide and sulfur oxides, results of studies of lung function in populations in areas exposed to photochemical/oxidants pollutants have been equivocal. Chronic obstructive respiratory disease (CORD) and progressive decrement in lung function are probably caused by multiple factors acting either together or in a sequential pattern. These include such identified factors as smoking, recurrent childhood respiratory episodes, bronchospastic disease, and occupational exposure to respiratory irritants. Evidence has been accumulating that chronic exposure to SO_2 and particulates in the ambient air may also play a role in the initiation and/or aggravation of CORD. Although there are many reports of acute effects associated with high concentrations of photochemical oxidants, there are few reports of long-term effects.

Los Angeles County is an excellent natural laboratory for studying the respiratory effects of various pollutants because of its topography and numerous micro-climates. Studies there are also facilitated by the existence of a uniform network of air quality monitoring stations maintained by the South Coast Air Quality Management District which are reviewed by the California Air Resources Board.

The objective of the studies described herein was to determine if changes in lung function test results over time correlated with levels of pollutants occurring concurrently and historically at place of residence. The study was designed to include a community exposed to primary pollutants characterized by high levels of SO_2 and hydrocarbons and a community exposed to high levels of photochemical oxidants, the most characteristic group of pollutants in the Los Angeles basin.

Methodology

Study areas were selected in four areas of Los Angeles County. These areas were selected on 1) the basis of levels of air pollution, 2) proximity to one of the monitoring stations of the Southern California Air Quality Management Districts and 3) demographic similarity to each other according to the 1970 census. The four study areas were selected to include one area exposed to low levels of photochemical oxidants located in the Antelope Valley (Lancaster), one area exposed to high levels of primary pollutants (Long Beach), one area exposed to high levels of photochemical oxidants (Glendora), and one area exposed to moderate levels of photochemical oxidants (Burbank).

Prior to starting lung function testing in each study area, public service announcements were placed in the local media. Letters were sent to heads of households by obtaining names from reverse directories and voter registration files. Neighborhood representatives were recruited from the study community to enumerate households and to make appointments for all residents of the study area who were 7 years of age or older.

At the Mobile Lung Function Laboratory participants completed a) a questionnaire including questions on history of respiratory symptoms and diseases, occupational history, past exposures to substances associated with respiratory injury, smoking and residence histories, and b) a series of lung function tests including (in the sequence in which they were administered) (1) determination of expired carbon monoxide concentration, (2) lung volumes determined by whole body plethysmography, (3) ventilation efficiency using the single breath nitrogen and (4) respiratory flow rates using electronic volume spirometry.

A number of procedures were implemented to evaluate the reliability and to estimate the validity of the lung function test results. These included (1) immediate retesting of every tenth participant, (2) retesting of a 3% probability sample of participants at the UCLA Pulmonary Function Laboratories, (3) retesting in each area of 100 participants three times during the year, (4) calibration of the Mobile Lung Function Laboratory with the UCLA Pulmonary Function Laboratory before field testing in each study area using volunteers tested concurrently, and (5) comparison of lung function test results with levels of specific pollutants on day of testing.

The levels of air pollutants in the four study areas were concurrently monitored by stations of the Southern California Air Quality Management District. Each of these stations continuously recorded levels of total oxidants, nitric oxides, nitrogen dioxide, total oxides of nitrogen, total hydrocarbons (not in Long Beach), carbon monoxide, sulfur dioxide (not in Lancaster) and total particulates. Twenty-four hour sulfates were recorded in Burbank, Long Beach and Glendora from 1977. Participants completing lung function testing at baseline were invited to undergo retesting five years later (six years in Long Beach) after baseline examination. The procedures and tests performed were the same as those used at baseline. Participants who had moved too far from the original study area to undergo lung function testing were asked to complete a questionnaire on respiratory symptoms, history of respiratory disease, smoking history and reasons for moving from the study area.

Results

Reported symptoms and the results of spirometric tests and the single-breath nitrogen tests are given in this report. Results are not reported for the plethysmographic test because review of the comparisons between the Mobile Lung Function Laboratory and the UCLA Laboratory indicated that the plethysmographic measurements were not reliable at baseline testing. Thus, the change from baseline to retesting could not be determined. Except for the symptoms, the results of the tests are reported as the annualized rate of change. This rate is achieved by dividing the observed change in the test performance in the interval between baseline and retesting by the number of elapsed months and then multiplying by 12 months.

The results for the Burbank study area are not included in this report because the results were internally inconsistent and not in agreement with the UCLA laboratory. In the opinion of the investigators the results could not be corrected by a simple adjustment equation.

From 46% to 59% of those tested at baseline completed all of the lung function tests at the repeat examination. The major problem was not refusals to be retested, but the relatively high proportion of individuals who had moved from the study area. Comparisons were made of the mean observed/expected (O/E%) FEV_1 among those retested and those not retested. The (O/E%) FEV_1 values at baseline were lower for individuals who refused to be retested but were similar among individuals who were and were not retested.

The potential effect of a number of factors to confound the results were considered. No correlations were seen between the level of specific pollutants on day of testing and lung function test results using a variety of analytic strategies, suggesting that the level of pollutants at the time of testing was probably not a major confounder of test results. The mean height and age among the participants in the three study areas were similar. Over 90% of the homes in each of the three study areas used gas heating. A higher proportion of participants in Lancaster, the clean area, had a history of working in an occupation associated with potential respiratory impairment. The majority of commuters from the Glendora study area commuted to areas of lower levels of pollutants whereas the small proportion of commuters in the Lancaster study area tended to commute to areas of higher levels of pollutants. This pattern would tend to reduce the probability of observing real differences between communities.

The symptoms included in analysis were cough, cough with sputum production, wheeze and diagnosis of asthma, bronchitis and/or emphysema. Although the incidence of symptoms tended to be greater among smokers than never-smokers, there was no consistent relationship for either the development of new symptoms or the loss of symptoms among the three study areas in either children or adults.

The mean annual change in the spirometric indices and the single-breath nitrogen test for never-smoking residents who were 7-24 years and 25-59 years of age at baseline and for smoking individuals who were 25-59 years of age at baseline were analyzed separately. For each of the pulmonary function variables reported, the mean change for Lancaster was compared with the mean changes for Glendora and for Long Beach. The changes in lung function test results for both males and females in the 19-24 age group were the most favorable in the Lancaster cohort for each of the six lung function tests reported (FEV_1, FVC, FEF_{25-75}, $\mathring{V}_{75}$, $\mathring{V}_{50}$, ΔN_2). In the groups between 7 and 18 years of age no consistent differences were noted between the three study areas except for the single-breath nitrogen test result which was consistently better among the Lancaster participants (except compared to males 19-24 in Long Beach).

Among participants 25-59 years of age at baseline, the rate of decline among smokers was greater than among never-smokers. The magnitude of the difference however, was less than might have been expected probably due probably to the fact that 23-34% of the males and 13-24% of the females had given up smoking in the interval between baseline and retesting and that a lower proportion of smokers, than never smokers were retested. With only two exceptions among smoking females, the rate of change in each of the pulmonary function tests was more favorable among Lancaster adult residents than among adult residents in the Long Beach or Glendora study areas. In 13 of the 24 comparisons of Glendora adults with Lancaster adults the mean change was significantly smaller in Lancaster, 9 of them at the $p < .01$ level. In 17 of the 24 comparisons of Long Beach with Lancaster the mean change was significantly smaller in Lancaster, 12 of them at the $p < .01$ level. In no instance where a statistically significant difference was observed between study areas was the rate of change more favorable in the two polluted areas.

Conclusions

Population studies of the respiratory effects of long-term exposure to air pollutants are subject to many problems. This study is no exception. Nonetheless, the analysis of the impact of potential confounders and the consistency of the test results suggest that chronic exposure at place of residence is associated with unfavorable changes in lung function. These observations should be confirmed by additional studies. They raise sufficient questions, however, to suggest that current alert levels for air pollutants in the Southern California basin which are based primarily on acute responses may not be protecting residents from chronic respiratory effects of pollutants occurring at levels lower than the established alert levels. This, in turn, raises serious questions about the need for more stringent regulation of air quality.

Roger Detels
AO-133-32

ABSTRACT

Changes over 5 years in the frequency of recorded symptoms and results of lung function testing were compared in three study areas in Los Angeles County. Residents in Lancaster were exposed to relatively low levels of oxidants; in Long Beach were exposed to high levels of sulfur dioxide, sulfates, hydrocarbons and oxides of nitrogen; and in Glendora to very high levels of photochemical oxidants and particulates. Changes were more favorable among never-smokers than among smokers. There were no differences between communities in the development or loss of reported symptoms. In adults, the majority of the test results were more favorable in residents of the low pollution area (Lancaster) than in the other two areas. Thirteen of 24 comparisons with Glendora and 17 of 24 comparisons with Long Beach were significantly more favorable for Lancaster participants. In no instance was a significant difference noted which was not more favorable for Lancaster participants. In children, consistently more favorable results in the single-breath nitrogen test were observed for Lancaster participants. The results suggest that residence in areas exposed to high levels of pollutants in Los Angeles County may be associated with unfavorable changes in lung function. This observation suggests that it may be necessary to review the currrent rationale for establishing acceptable levels of pollutants in the air over Los Angeles County.

I. OBJECTIVES

A. Background

This was a proposal to continue studies of the relationship between long-term exposures to different species and levels of pollutants in four communities and the respiratory health of the residents of these communities. Cohorts of residents of these geographically defined study areas had been formed from cross-sectional surveys carried out between 1972 and 1977[1-4]. The demographic characteristics of the four study areas and the sex, and the race distribution of those completing base testing are given in Tables 1 and 2[2,11,14]. The study areas included Lancaster (exposed to minimum levels of man-made pollutants), Long Beach (exposed to SO_2, particulates and other primary pollutants), Burbank (exposed to moderate levels of photochemical oxidants and other secondary pollutants) and Glendora (exposed to high levels of photochemical oxidants, particulates and SO_4). Two of the four cohorts (Burbank and Lancaster) had been retested five years after baseline testing. This proposal was specifically to complete retesting of the cohorts in the two communities subject to high levels of primary and secondary pollutants (Long Beach and Glendora), and to compare observed changes with levels of pollutants occurring in the two cohorts over this time period as well as historically to changes in the cohort in Lancaster which was subject to lower levels of pollutants.

B. Objectives

The principal objective of the cohort studies described in this report was to determine if changes in lung function test results over time were associated adversely with historical and concurrent levels of pollutants occurring in the ambient air at the place of residence of the four cohorts studied. The pollutant mixes studied included 1) photochemical oxidants and other secondary pollutants and 2) primary pollutants. Two secondary objectives were 1) to see if alterations in specific lung function tests were associated with the two different types of exposure and 2) to see if a dose response relationship was seen with different levels of exposure to photochemical oxidants. This latter objective could not be met due to technical problems in the cohort exposed to moderately high levels of photochemical oxidants (see results section).

II. APPROACH

A. Methodology

1. Establishment of cohorts

Prior to this proposal, cohorts of residents of four geographically defined areas exposed to different levels and types of air pollutants had completed baseline lung function testing at a Mobile Lung Research Laboratory[1-3,5]. Each member of these cohorts completed a modified NHLI respiratory questionnaire, volume spirometry with electronic recording of the entire flow volume curve (air vs. helium/G_2), the single-breath nitrogen washout curve, and whole body plethysmography. The individual cohorts ranged in size from 3403 to 4509 residents. A total of 15,164 individuals were examined at baseline.

The geographically defined areas were selected to have similar distributions of socioeconomic factors and racial groups, to contain or be adjacent to a continuously monitoring station of the Southern California Air Quality Management District, and to be historically exposed to different types and levels of pollutants in community air (Table 3). Pollutant levels for Burbank are not given as this cohort was excluded from analysis (see below).

The interlaboratory variability of the test procedures was evaluated by reexamining, at the UCLA Pulmonary Function Laboratory, a 3% probability sample of residents completing lung function testing at the Mobile Lung Research Laboratory[2]. Intralaboratory variability was evaluated by immediate retesting of every tenth participant at the Mobile Lung Research Laboratory and by reexamination of 100 residents of each study cohort four times a year[1,2,6,14].

Details of the recruitment and test procedures used for the baseline studies have been reported[1,2,14].

2. Relocating cohorts

Relocation of members of the cohorts was the responsibility of the field coordinator and the neighborhood representatives who had been selected from the community being tested. In many instances these were the same neighborhood representatives who were responsible for the successful recruitment of residents at the time the cohorts were originally formed.

The current residence of members of the cohorts in the three areas had been updated annually. The return form included a request for the name and address of a "contact person" who would know how to reach the participant in the future.

Letters announcing the initiation of reexaminations in each area were sent to the most recent address with the request for notification of forwarding address and return postage guaranteed. Current addresses for those individuals for whom there was no forwarding address were sought through the designated contact person, canvassing of neighbors, a check of the Department of Motor Vehicles' driver and vehicle registrations, review of telephone directories for areas designated by neighbors, and finally by a review of death tapes.

Letters were sent to all members of the original cohort still residing in the area indicating that retesting of all participants was currently underway in their respective community and that they would be contacted by a neighborhood representative who would update their household roster and set up an appointment for each family member to revisit the Mobile Lung Research Laboratory. As previously, the mobile laboratory was located within walking distance of the resident's home.

For those individuals who did not keep their appointments, a follow-up telephone call was made immediately. If unsuccessful, repeated attempts were made to reschedule the residents for lung function testing.

Individuals who had changed residence since the original testing fell into three categories: those remaining within the study area or adjacent to it, those moving out of the Southern California area, and those lost to follow-up. Individuals remaining within the study area or in immediately adjacent areas were visited and scheduled in the same manner as individuals within the study area who had not moved. Respiratory questionnaires with additional questions on reasons for moving were sent to those moving out of the Los Angeles area. The cover letter also asked them to contact us if they would be near the study area in the future so that we could arrange to retest them.

The initial letter to residents who remained in the study area or nearby contained a return envelope and form requesting their current telephone number so that the neighborhood representative could call them back in order to work out the most acceptable time and place for retesting them. In order to encourage their participation the neighborhood representative offered to pay travel expenses for retesting. For those individuals who did not indicate their current telephone number, their number was sought by review of phone directories for the area, directory assistance and reverse directories.

Concurrent with the retesting of the cohorts in Long Beach and Glendora we requested that articles concerning the program appear in the local newspapers and that public service announcements be made over the local radio and television stations. The schools in the neighborhood and the community organizations were asked to cooperate in announcing the retesting in the community and in encouraging the cooperation of all members of the cohorts.

The key member of the program staff involved with recruitment of residents was the neighborhood representative. They were selected from among applicants on the basis of their performance in the training program. Whenever possible, the same neighborhood representatives who worked during the baseline screening in that community were rehired.

3. Respiratory evaluation & lung function testing

Interview schedule: A copy of the interview schedule is included in Appendix 13. The interview schedule included an updating of the symptom, smoking, respiratory disease, residence and occupational histories and, in addition, contained questions about commuting patterns, percent of time indoors and outdoors, and type of heating used in the residence.

To facilitate analysis of symptoms of respiratory disease, criteria were developed for each of the symptoms[14]. Individuals were considered to have definite criteria of cough if they reported coughing first thing in the morning in bad weather on most days for as much as three months of the year, or first thing in the morning on more than 50 days in a year for more than 2 years. Individuals were considered to have definite criteria of cough and sputum if they reported coughing and bringing up phlegm, sputum or mucus first thing in the morning in bad weather, at other times during the day or night in bad weather, on most days for as much as 3 months of the year, first thing in the morning on more than 50 days a year, or later in the day on more than 50 days in a year for 2 years or more. Individuals were considered to have definite criteria of wheezing if they reported their breath ever sounding wheezing or whistling on more than 19 days in a year and/or they had ever had attacks of shortness of breath and wheezing. Individuals were considered to have asthma bronchitis and/or emphysema if they had been told by a physician that they had one or more of these diseases.

Smokers were individuals who had smoked within two years of baseline testing. Individuals who reported stopping smoking in the interval between baseline and retesting were still included among smokers.

Tests of lung function: The following tests of lung function were administered to members of the cohort (listed in the order in which they were performed):

(a) End tidal CO concentration

(b) Height, weight, pulse and blood pressure measurement

(c) Body plethysmography (multiple trials): thoracic gas volume (V_{TG}) at resting; end-expiratory position (FRC); expiratory reserve volume (measured spirometrically by having subjects completely exhale to residual volume immediately after determination of FRC); residual volume and total lung capacity (by calculation); airway resistance (R_{AW}) and specific airway resistance (R_{AW} times V_{TG})

(d) Single-breath nitrogen washout curve (multiple trials): $\Delta N_{2_{750-1250}}$, $\Delta N_{2_{750-1750}}$, and $\Delta N_{2_{500-1000}}$, for low-volume subjects, closing volume/vital capacity fraction, closing volume/total lung capacity fraction

(e) Electronic spirometry (multiple trials with permanent recording of the entire flow volume (FEV_1, FEV_2, FEV_3, etc.); forced expiratory flow rates ($FEF_{200-1200}$, FEF_{25-75}, FEF_{50-75}, FEF_{75-85}, and others, if indicated); instantaneous flow rates at various percents of FVC ($\dot{V}_{25}$, $\dot{V}_{50}$, $\dot{V}_{75}$, $\dot{V}_{90}$, and $\dot{V}_{max}$)

(f) Helium/oxygen isoflow at $\dot{V}_{50}$ and other points (not administered at baseline)

4. Test-retest variability

Intra-laboratory variability of the tests was estimated by retesting every 10th participant within ten minutes. Seasonal variability had been estimated by retesting 100 participants three times during the year. No differences were found. Interlaboratory variability was estimated by retesting a 3% sample at the UCLA laboratories[2,9,10,14].

5. Validation & quality control

Standardization and calibration: Before initiation of retesting in Long Beach and Glendora, the test equipment on the Mobile Lung Research Laboratory was cross-calibrated to equipment at the UCLA Pulmonary Function Laboratory employing volunteers who went through the same tests in a random order at both these laboratories as done in previous years[2]. In addition, all equipment on the Mobile Lung Research Laboratory was calibrated before, during and after each day's testing and the test results reviewed quarterly.

Validation: To determine if calculation of rates of change in lung function test results were related to differences in laboratory procedures all members of the cohort who were included in the original 3% probability sample which underwent retesting at the UCLA Pulmonary Function Laboratory at the time of baseline screening were invited once again to undergo further testing at the UCLA laboratory. At the time of the baseline examination, approximately one-half of this sample was randomly selected from all residents 18 years of age or older who completed testing at the Mobile Lung Research Laboratory; the other one-half were selected on the basis of definite or probable respiratory abnormalities according to the results of the Mobile Lung Research Laboratory tests. Retesting in the validation laboratory of this original cohort (which had already undergone validation studies at the time of the baseline examination) was important (see results) from the standpoint of determining whether changes in interlaboratory differences had occurred which could reflect changes, or "drift," in the characteristics of the field instrument over the five-year interval between the baseline and present examinations. Although cross-sectional comparisons could be made at baseline and retest, any differences observed could be due to differences in the populations tested because of aging and dropouts. Comparisons of the change in individuals tested twice, therefore, gave a better evaluation of the comparability of measurement of change in the two laboratories. We also invited for retesting in the validation laboratory an additional randomly selected sample of individuals 18 years or older who had completed retesting in the mobile laboratory. The retesting of these individuals who had not previously undergone validation studies served as a satisfactory mechanism for determining the current reliability of the field laboratory; more important, by permitting comparison of current field laboratory-reference laboratory differences with those observed at the time of baseline testing, such retesting in the UCLA laboratory provided a needed check on the occurrence of "drift" in the field instrument. As an inducement individuals selected for validation studies at UCLA were offered a $10.00 fee in addition to travel expenses.

Letters of invitation for retesting at UCLA, explanation of the procedures to be performed and the reason for the studies, telephone contacts, reminder letters, instructions regarding parking and location of the laboratory, and follow-up letters to the subjects and their physicians indicating test results were handled through the UCLA Pulmonary Function Laboratory.

Upon arrival at the UCLA laboratory at 9:00 AM on the day of the study, subjects were given further information regarding the tests to be performed and were requested to sign an informed consent form. They then underwent the same studies that were performed in the mobile laboratory as follows:

a) Respiratory questionnaire (cohort project interview schedule)

b) Spirometry (using a 10-liter Stead-Wells spirometer) and spirometry and flow-volume curves (generated by an 11-liter rolling-seal electronic spirometer: Cardio-Pulmonary Instruments, Inc., Model 220) from which the following indices were calculated: slow vital capacity FVC, FEV_1, $FEF_{200-1200}$, FEF_{25-75}, peak maximum flow rate ($\dot{V}_{max}$) and maximum flow rates at 25%, 50% and 75% of forced expiration and maximal voluntary ventilation. Calculations were made using the tracing representing the best effort on the basis of FEV_1, if the latter was associated with an FVC which was at least 95% of the best FEV_1

c) $\dot{V}_{max50}$, $\dot{V}_{max25}$, and volume of isoflow calculated from maximal expiratory flow-volume curves generated during breathing of air and an 80% helium-20% oxygen mixture

d) Helium-dilution lung volumes using a 13.5-liter spirometry (Warren E. Collins, Inc.) for determination of functional residual capacity, expiratory reserve volume and residual volume. Although this test was not performed in the field laboratory, it was included in the battery of validation laboratory tests because it provided a further check on the validity of plethysmographically determined thoracic gas volume and on the total lung capacity calculated from single-breath nitrogen washout for determination of closing capacity.

e) Closing volume, closing capacity and slope of phase III of the single-breath nitrogen washout curve $\Delta N_{2_{750-1250}}$ and ΔN_2/liter) using an electronic spirometer, a rapidly-responding nitrogen analyzer (Cardio-Pulmonary Instruments, Inc., Model 410), and a multichannel oscilloscopical recorder (Electronics for Medicine, Model DR-8).

f) Airway resistance and thoracic gas volume at functional residual capacity using a 600-liter constant-volume body plethysmograph (Warren E. Collins, Inc.).

g) Single-breath diffusing capacity for carbon monoxide using a water-seal spirometer and bag-in-box system (Warren E. Collins, Inc.) with helium and infra-red CO_2 analyzers (Beckman Instruments, Model LB2). This test, although not performed in the mobile laboratory, served as a useful indicator of probable emphysema in individuals with airflow obstruction.

h) End-expired CO using an electrochemical CO analyzer (Ecolyzer Series 2000).

6. Data management

A computer-based data management system was designed for test results from the baseline studies and from retesting of the cohorts. The base file contained the household roster. The second-level file contained results of the field questionnaire and pulmonary function tests for the baseline testing in each area. Household roster information on specific individuals undergoing field testing had been incorporated into this second-level file. The third-level file contained the results of field and validation lung function tests for the 3% probability sample invited to undergo retesting at the UCLA laboratory at baseline. The fourth file included name, address, telephone and identification numbers used for follow-up notification for the retesting of cohorts. This was the only file which contained both the name and identification number of the individual residents and has been kept under limited access. The fifth file included the air pollution and climatologic data obtained from the four monitoring stations of the Southern California Air Quality Management District.

At the time of retesting new files were created to include both baseline and retest information. Allowance was made on these new files for household members who had become age-eligible at the time of retesting. All individuals were included in the new files regardless of whether they completed retesting. For those individuals not completing retesting the cause for non-completion was included in the file.

Additional files were created for the 10% sample undergoing immediate retesting at the mobile laboratory and the 3% sample retested at UCLA. These files were used to estimate the intralaboratory and interlaboratory variability of the test procedures. Computer files of air pollution and climatologic data for each of the four stations of the Southern California Air Quality Management District and other sources were maintained for the entire period of field testing.

Data from the modified NHLI respiratory questionnaire and the household roster were collected on self-coding forms. That data and the data from the Mobile Lung Research Laboratory were entered into computer tape. Data from electronic volume spirometry and the single-breath nitrogen washout curve were recorded directly onto 9-track computer tape which was compatible with the IBM system being used at UCLA. A computer program had been developed which selected the best breath for determination of the spirometric indices[14]. In the event of breakdown of the recording at the Mobile Lung Research Laboratory, a hard copy backup was maintained on all testees. Errors of the recording device were minimized by rapid rechecking of all data tapes from the mobile laboratory within 24 hours of retesting and before testing began the following day. Editing of data was done by computer using a program to identify outlying or unusual values. These were printed for verification and/or corrections.

An important component of this study was the cooperation of members of the four cohorts. In order to maintain this cooperation a rapid notification system had been developed using a computer program which identified individuals with abnormal responses. This program automatically generated letters of notification, providing a general assessment in lay terms of the results of the lung function testing to the testee. The results of the specific tests of lung function were also sent to the physician designated by the participant.

7. Monitoring of air pollution levels

The quality of air in the three communities was continuously monitored by stations of the Southern California Air Quality Management District (formerly the Air Pollution Control District) of Los Angeles County as follows:

Lancaster, Station 82
Long Beach, Station 72
Azusa (Glendora), Station 60

Each of these stations recorded continuously (except for calibration and chemical restocking periods) the following: total oxidants, nitric oxide, nitrogen dioxide, total oxides of nitrogen, total hydrocarbons and nonmethane hydrocarbons (not in Long Beach), carbon monoxide, sulfur dioxide (not in Lancaster), and total particulates. Twenty-four hour sulfates were recorded from 1977 in Long Beach and Glendora.

Description of the instrumentation employed, technical maintenance, calibration techniques and validation procedures, and the frequency with which these were done are contained in the Quality Assurance Plan for Ambient Air Monitoring, July 1977, Technical Services Division/South Coast Air Quality Management District.

The output of the Southern California Air Quality Management District is reported by contractual arrangement to the California Air Resources Board. The contract requires the following schedule of calibration of the monitoring and analytical instruments:

"All air monitoring instruments shall be calibrated by either the State or by the Contractor in accordance with procedures acceptable to the State. The Contractor shall provide copies of its current instrument calibration procedures and chemical analysis procedures for all pollutants monitored upon submittal of this contract, but in no case later than 90 days after receipt of the contract. If, in the State's opinion, the Contractor's procedures are significantly different from State procedures, the Contractor shall use State procedures or furnish the State with evidence of equivalence. In addition, the State shall have the discretionary right to conduct referee calibrations for each parameter at the Contractor stations.

"The Contractor shall calibrate air monitoring and analytical instruments on at least the following schedule:

Oxidants (Ozone)	Semi-Annually
NO, NO_2, NO	Annually
NDIR CO_2	Annually
FID Total Hydrocarbon	Annually
SO_2	Annually
Hi-Vol	Semi-Annually
COH (flow rate calibration)	Semi-Annually

Sulfate and Nitrate Spectrophotometers - Concentration	Quarterly
Sulfate and Nitrate Spectrophotometers - Spectral Response	Semi-Annually
Lead, Spectrophotometer - Concentration	Quarterly

"Instruments shall be recalibrated after major repairs or modifications. A copy of each calibration report shall be submitted to the State within thirty days of the instrument calibration date. Information on the calibration report cover shall include: parameters monitored; method of calibration; manufacturer, model, and serial number of instrument; date of calibration; and results in percent deviation from true, both before and after adjustment, and percent deviation, from last calibration.

"For calibrations of carbon monoxide and total hydrocarbon analyzers, the Contractor agrees to use carbon monoxide and methane span gases traceable to State or NBS standards. The Air Resources Board will provide compressed gas cylinders of the proper concentrations for multi-point calibrations upon request."

The validity of air quality data with which physiologic data was related was, therefore, at levels satisfactory to EPA and the State of California Air Resources Board technology.

The ability of fixed monitoring stations to quantify air quality levels in neighborhoods around the station (representativeness) had been evaluated by several techniques in the past. Mobile laboratories have simultaneously sampled air at various radii around the stations and compared data with those of the station. Study of levels in a series of stations, with relation to windflow patterns, had generated a body of data concerning the duration and flux of concentrations of substances. Isopleths have been developed for various pollutants occurring in the Southern California Air Basis[16,17]. Studies to further interpolate values between stations and to provide more precise "neighborhood" estimations were also done by the Technical Services Corporation[18]. A summary table of representativeness for the census tracts proximate to the monitoring stations is shown below:

Oxidant	Uniform over 10-20 miles
NO_2	Uniform over 5-10 miles
SO_2	Uniform over 10-20 miles, except where power sources within the range contribute
SO_4	Uniform over 15 miles
CO	Not uniform
Hydrocarbon	Uniform over 5-10 miles, except where power sources within the range contribute

Use of fixed monitoring stations: Because we were interested in the effects of long-term exposure to pollutants, we selected study areas historically exposed to very different levels and types of pollutants which were located either adjacent to or within a short distance downwind of the stations of the

Southern California Air Quality Management District cited above which continuously measured levels of selected pollutants[1,3,5].

In the Long Beach study area no residences within the study area were more than 1/2 mile from the monitoring stations. Most of the residents of the Lancaster study area lived within 1 mile of the monitoring station. No residence in the Glendora study area was more than 4 miles downwind from the monitoring station in Azusa used to estimate pollutant exposures occurring in that study area. Measurements of total oxidants and other major pollutants except carbon monoxide, therefore, may slightly underestimate exposures occurring in the Glendora study area. Each of the study areas except Lancaster was less than one square mile in area and had no topographical barriers between it and the monitoring station. In Lancaster the majority of the population in the study area was contained within a one square mile area nearest the monitoring station.

There are several areas in which documentation of pollutant exposures have been inadequate. Hydrocarbon and particulate levels were not regularly measured at the Long Beach station but evidence from another study and the location of the station downwind from the petrochemical industry suggests that levels of hydrocarbons and particulates were high. Particulates have been measured using the high volume sampler technique. Techniques with separation by particle size would, of course, have been more helpful. Although isopleth studies have provided estimates of the representativeness of measurements of particular pollutants made at a fixed monitoring station, validation of these estimates using a mobile or portable sampler to measure levels concurrently was not carried out systematically.

8. Analyses

The major objective of the analyses was to determine whether there was a relationship between changes in lung function test results in areas exposed to different levels and types of air pollution--Los Angeles County. In order to accomplish this goal it was necessary to consider potential problems of misclassification due to factors associated with such factors as the test procedures, measurement of pollutants, characteristics of the participants, response characteristics and factors such as commuting patterns, etc. Thus, the initial analyses were concerned with:

a) variability of the test procedures
b) characterization of non-respondents
c) characterization of the pollutant exposure for the four study areas
d) the consistency and predictability of individual tests of lung function
e) individual differences in lung function test results between baseline and retesting as well as comparisons of these changes between residents of the four study areas
f) other environmental, familial and constitutional factors which may be associated with changes in lung function testing performance or the development of chronic obstructive respiratory disease
g) the relationship of high concurrent exposures to test performances in residents with reported reactive airways disease.

a) Variability: The variability of test procedures may be due to variability in the procedures themselves (instrumentation), variability in the individual being tested, variability between a group of individuals, and/or variability due to outside factors such as seasonal factors.

The intralaboratory variability of the spirometry field tests was evaluated by comparison of initial and retest values on the 10% sample of participants who underwent immediate retesting within several minutes of the original testing. Scatter diagrams and indices of co-relationship were obtained and studied. Test-retest results were very similar especially for the major spirometric tests (FEV_1, FVC, $FEF_{25-75\%}$).

Variability of the field test measurements as well as possible seasonal or time related changes may reflect age, sex, and other physical measurements such as height, etc. Part of the analysis of the data was to explore the regression relationships of lung function measurements to selected measurements such as age, weight and height. Regression equations used to adjust for these factors in the cross-sectional analyses are given in Table 4.

Concurrent changes occurring in two or more test results were analyzed in the form of contingency tables or in the case of continuous variables, by correlation analysis.

The interlaboratory variability of the field tests was measured by direct comparison with observations made in a 3% probability sample retested at the UCLA Pulmonary Function Laboratory. Corresponding measurements in the field and in the UCLA laboratory were compared individually as well as by groups of variables.

Variability in the results of field laboratory tests related to changes over time in the performance characteristics of the measuring or calibrating instruments and/or in technical personnel could have led to consistent differences in field test results. Such differences might then be erroneously interpreted as representing real physiological changes over time in the cohort undergoing re-examination. Comparison of current interlaboratory (i.e., field laboratory-UCLA laboratory) variability with that determined at the time of baseline testing served as a needed check against such consistent errors.

b) Characterization of non-respondents: The results of retesting of lung function in the areas might have been affected by the characteristics of respondents vs. non-respondents. Therefore, individuals who have refused to undergo retesting, who have moved too far from the original study to be tested, who had been lost to follow-up, or who were too ill to be retested were characterized on the basis of reasons for non-response, demographic, familial and occupational factors, respiratory history and lung function performance at baseline.

c) Characteristics of pollutant exposures: The California Air Resources Board provided us with tapes of pollutant levels continuously measured at the monitoring stations of the Southern California Air Quality Management District. From these tapes we established individual pollutant levels occurring in the area at the time of testing for each resident and included this as part of the individual's basic record. The information from these tapes was used to characterize pollutant exposures during the interval between initial testing and retesting in each of the the four study areas.

d) Consistency and Predictability of Individual tests: Preliminary analysis of the predictability of the various tests was performed. For example, performance on spirometry at baseline was found to be associated with a greater decline between baseline and retesting.

The consistency of the individual tests was tested by comparison of the same individuals within ten minutes of initial tests and by retesting of a sub-sample at the UCLA Pulmonary Function laboratory. Consistency was good for FEV, FVC, but varied for the other tests[2].

e) Individual differences in test results between baseline and retesting: The major analytic strategy reported herein has been the mean of individual differences between lung test results at baseline and those at retest. This strategy reduced problems associated with intersubject variability. The results of this analytic strategy are included in Tables 18, 19 and 21.

f) Role of other factors: The role of other factors in the initiation or promotion of respiratory impairment and/or disease was considered by comparing the history of such factors as individual smoking patterns, smoking patterns within households, recurrent episodic infection in childhood, residence, and familial experience with chronic respiratory disease in individuals who had demonstrated a greater degree of respiratory decrement than those who did not demonstrate such a decrement. It was important to consider variables which affect individual exposure to pollutants such as proportion of commuters, areas to which residents commute, the time spent in commuting, the types of heating-filtering systems used in the home, etc. The distribution of these are discussed in the results section and the implications considered in the discussion section.

g) Effect of acute exposures: Although the primary objective of this study was to determine the relationship of long-term exposure to specific types and levels of pollutants in community air and respiratory health and the predictiveness of specific tests of lung function, the relationship of acute exposure to specific pollutants was evaluated by correlating the lung test performance of individuals to levels of various pollutants on the day of testing.

ANALYTIC STRATEGIES

The next step was to consider the appropriate outcome variable. It was clear that values at retest were dependent in part on the baseline values. For that reason, the annualized mean of the absolute change for each participant was selected (e.g., incidence of symptoms, ΔFEV_1, ΔFVC, $\Delta N_{2_{750-1250}}$--see results section). Consideration was also given to using O/E as an outcome variable, but the use of prediction equation introduced an additional element of variability and were not suitable for those tests not dependent on height, weight and/or age.

Initial analyses included regression at the outcome variable (ΔFEV_1, etc.) with the many variables on which data was collected. Other methods of analysis including use of certain regression techniques and analysis of variance procedures were considered, but for the initial presentations of results the stratification of results on age, sex, smoking status and place of residence was selected as providing the clearest presentation. Incidentally, changes in the outcome variable did not correlate strongly with either the baseline measurements or with age.

The question as to the normality of the data could be quite relevant from two points of view: whether we wish to talk about percentiles of the distribution of individuals, or whether we basically want to compare mean values. We had inspected a large number of sample distributions (all of those referred to in the report) and found that none were strikingly non-normal (i.e., J or U shaped) although with the larger samples several were "significantly different" from normal. This was particularly true of the data collected on young participants where there were large changes in mean over age. These distributions are really mixtures and almost any distribution could be obtained by a choice of an age distribution--there is no obvious age distribution of particular interest.

This lack of normality implies that care must be taken if moderately extreme percentiles were desired and in fact we did not address this question. In the report we have only used tests which, even for the relatively small sample sizes, are not overly sensitive to the normality assumption. For the young ages the results are given in two year age groups which reduces the variability due to age.

III. RESULTS

A. Organization of Results

Although retesting of the cohort in Burbank and Lancaster had been completed before the current project was funded the results are given for all the cohorts since it is the comparison of results between the areas with different types and levels of air pollutants that provides the best impression of the significance of this study and which addresses the possible relationship of pollutant exposures to changes in lung function.

Results are given for reported symptoms, spirometric tests and the single-breath nitrogen test. Results are not given for plethysmographic tests because review of the comparisons between the mobile lung function laboratory and the UCLA laboratory, of the calibration procedures performed at the beginning of testing in each area and of the actual tests values indicated that these measurements were not reliable at the baseline testing[2]. Thus, change from baseline to retesting could not be determined for the plethysmograhic tests.

B. Interval between Baseline Testing and Retesting

Retesting of the cohorts in the study areas in Lancaster, Burbank and Glendora was carried out on the fifth anniversary of the baseline studies. Because of funding logistics the interval between baseline testing and retesting in Long Beach study area was six years. In order to make the reported results comparable between study areas, results below are reported as the annualized rate of change.

C. Levels of Pollutants During the Study Period

Baseline testing was initiated first in 1972. Retesting was completed in 1982. The means of the peak hourly values for sulfur dioxide, oxidants, oxides of nitrogen, nitric oxide, and nitrogen dioxide and the 24 hour total values for sulfates and particulates are given in Table 3. The levels of all pollutants except oxidants were lowest in the Lancaster study area. Levels for oxidants in Lancaster were above those observed in Long Beach.

Of the three study areas, Long Beach was exposed to the highest levels of sulfur dioxide and oxides of nitrogen, including both nitrogen dioxide and nitrous oxide. The levels of oxidants in Long Beach were the lowest of the three study areas.

Residents of the Glendora study area were exposed to the highest levels of oxidants and total particulates. Levels of sulfate and nitrogen dioxide, however, were close to those observed in Long Beach and considerably higher than observed in Lancaster.

In summary, Lancaster can be summarized as having relatively low levels of all pollutants, although the levels of oxidants occurring there are higher than reported in many other areas in the United States. Long Beach could be characterized as having high levels of sulfur dioxide, sulfates and oxides of nitrogen. Although hydrocarbons are not measured at the Long Beach monitoring station isopleth studies confirm the high levels of hydrocarbons in the study area which would be expected because of its location downwind from many oil refineries. Glendora can be characterized as having high levels of oxidants and particulates and intermediate levels of sulfates and nitrogen dioxide. There, of course, may be differences among the three study areas in other pollutants which are not measured.

D. Exclusion of the Burbank Cohort

The results for residents of the Burbank study area have not been included in this report and in publications concerning these studies. The results for that study area were not consistent with those in the other three areas and were not internally consistent for the study area itself. Several specific analyses were performed to evaluate whether the results for the Burbank community could be included.

The first comparison of test results across the four communities for FEV_1, FEC and mid-expiratory flow rate (Table 5). Although the magnitude of the rate of decline in FEV_1 in Burbank was more consistent with that reported in some of the literature, the FEV_1 was clearly considerably lower than in the other communities investigated in this study[3,4,19,20]. This, however, was not sufficient reason for excluding Burbank. Several inconsistencies were noted within the different spirometric test results for Burbank itself. For example, among males in the age range of 25 to 59 years among smokers, the average annual decline in FEV_1 was 31 cc whereas the FVC did not decline but, in fact, increased an average of 9 cc each year among smoking males. Although these rates of change in FEV_1 and FVC were clearly lower than observed in the other three areas, the mid-expiratory flow rate was on the same order of magnitude. It is not logical that in this group there should be a small decline in FEV_1, an intermediate level of decline in mid-expiratory flow rate and in increase rather than decline in the FVC, particularly among current smokers.

Among never smokers the same type of phenomenon was seen. Again, there was an average annual decline in the 25-59 year olds of 29 cc in FEV_1, whereas the FVC declined only 4 cc per year. This apparently paradoxical relationship was seen among females where the drop in FVC was not commensurate with the drop in FEV_1, both among smoking and never smoking females. In all, the other communities, the rate of decline in FVC was commensurate with the decline in FEV_1 as would be expected. Although we searched exhaustively, we could find no reason for this disparity. We suspect that since this was the first community in which we initiated testing that there may have been a consistent error in the test procedures.

The second analysis was a comparison between the mean differences in FEV_1 in participants tested at the mobile laboratory and at the UCLA laboratory, both at baseline and retesting (Table 6). The disparity between the Mobile Lung Function Laboratory and the UCLA laboratory suggested that the rate of decline was underestimated by approximately 230 cc or 46 cc per year in Burbank over what would have occurred if the participants had all been measured at the UCLA laboratory. This was clearly a much larger underestimate of the rate of decline than occurred in the other three communities (minus 10 to minus 80 cc). Although we might have considered using these figures for adjustment, they were based on a small sample of participants and, thus, we felt uneasy about taking a correction factor based on a very small sample and multiplying it times a very large population of participants. On the other hand, we did feel that this comparison suggested that there were problems in the measurements made by the Mobile Lung Function Laboratory in the Burbank participants. These apparently went in different directions for Burbank only (an underestimate at baseline and an overestimate at retesting further exaggerating the problem).

Finally, a small subsample of volunteers in Burbank were reexamined a second time (three examinations in all) (Table 7). There was considerable disparity between the average annual rate of change estimated from the time 1 minus time 2 examination results, the time 1 minus the time 3 examination and the time 2 minus time 3 examination, which was evident in all sex and smoking groups. While the nature of the volunteer sample representing only a fraction of the participants at time 3 is not sufficient in and of itself, in our opinion, to suggest that Burbank be eliminated, this information coupled with the indication of inconsistencies within the spirometric measures themselves, the inconsistency of the results in comparison to the other three areas and the results of the comparison with the UCLA laboratory suggesting a very large error led us to the conclusion we could not present the data from Burbank with confidence. Thus, we made the decision reluctantly to exclude Burbank from further analyses.

E. Response Rates

The overall proportion of the participants 25-59 years of age who did not change jobs or residence because of a lung function problem who completed lung function testing and/or the questionnaire or died ranged from a high of

70 percent in Glendora to a low of 63 percent in Long Beach (Table 8). The proportion retested in Lancaster, 67 percent, was intermediate. A major problem was the proportion of participants who moved out of the study area in the interval between baseline testing and retesting. This ranged from a high of 44 percent of Long Beach residents to a low of 32-34 percent for the Glendora and Lancaster participants. The major problem was not refusals but individuals who either moved too far to be retested or who moved and were then lost to follow-up. The response rates for participants who remained within the study area ranged from a low of 80 percent in Lancaster to a high of 87 percent in Long Beach, including individuals who completed lung function testing, the questionnaire only or who were reported as dying. The proportion of individuals for whom lung function testing was actually completed ranged from 72 percent to 79 percent among residents remaining in the study area and from 46 percent of all residents 25-59 years of age in Long Beach to 59 percent of such residents in Glendora. The distribution of those retested in each area is reported in Tables 9a and 9b by age, sex and smoking category.

Because the proportion of participants actually retested regardless of resident status at retesting was low, an effort was made to determine if differences existed between those retested and those not retested using baseline information. Table 10 gives the proportion of individuals retested in each study area by sex and smoking status subdivided by whether their FEV_1 at baseline was above or below 75 percent of observed divided by expected. As might be expected, the response rates were higher among never smokers than smokers.

A second analysis to determine if there were differences between those who were tested and not retested was performed in Tables 11a and 11b by comparing the mean observed/expected value for FEV_1 among those retested and those not retested, the latter being further subdivided into those individuals who moved, those who could not be relocated, and those who refused to be retested. The mean FEV_1's for those who refused was lower in each study area than among those who were retested or who were not retested by virtue of moving. The values for individuals who were lost to follow-up were more similar to those individuals who moved than for those individuals who refused. The overall mean FEV_1 values among those retested was only slightly greater than the mean value for those not retested suggesting that the values observed for change may be a small underestimate of the actual rates of change for the entire cohort had it been completely retested.

F. Potential Confounders

In an epidemiologic study such as this there are opportunities for a number of related factors to confound the observations. In order to evaluate whether factors such as pollutant levels at the time of testing, and the type of heating fuel used in the home were potential confounders, a comparison was made of these factors among the three study areas.

Two analyses were performed to determine whether levels of pollutants at the time of retesting were affecting the test results. The first was a comparison of the lung function values in a sub-cohort of participants tested three times over the course of a year which corresponded with the various pollutant periods. No correlation was seen between test result and season of the year in which testing occurred in this subcohort[5]. The second analysis, shown in Table 12 was a comparison of the correlation between the residual observed minus expected value for FEV_1 and the level of pollutant occurring at the time of retesting for the major pollutants found in the three study areas. This comparison was done separately for males, females, smokers and never smokers. A negative correlation coefficient suggests a decreasing FEV_1 value associated with increasing levels of pollutant. Positive values would indicate an increase in the FEV_1 value concurrent with increasing levels of pollutant. No consistent correlations were observed between pollutant levels and residual values for FEV_1 values among any of the subcategories in any of the three study areas. These two analyses suggest that the level of pollutants at the time of testing were probably not a major confounder of test results.

The next comparison (Table 13) was of the height and age of participants 25-59 years of age among the three study areas. The mean age and height among males, both smokers and never-smokers, were remarkably similar among the three areas as was height among females. The females in Long Beach, however, were slightly older than the females in the other two areas. Although the rate of decline in FEV_1 between 25 years of age and 59 years of age was observed to be very small there is a possibility that the values for Long Beach females may be slightly overestimated in comparison to the values for females in the Lancaster and Glendora study areas.

As demonstrated in Table 14 the vast majority of homes in each of the three study areas used gas heating fuel. This is not surprising since electricity is more expensive in Southern California than gas. Although information about type of cooking fuel was not separately obtained, it is our impression that relatively few homes would use two different types of fuel for heating and cooking.

Another possible confounder would be the history of working in an occupation which might be considered hazardous to respiratory health. The proportion of residents with a history of working in hazardous occupations, however, was highest among participants in the Lancaster area, the area with the lowest levels of pollutants[9,10]. Thus, this type of bias would presumably have decreased the probability of observing a difference between the three study areas.

Another possible confounder would be commuting to areas of markedly different concentrations of pollutants than were occurring at the place of residence. This observation, however, would contribute to an observed difference only if residents of the areas subject to the highest levels of pollutants, Glendora and Long Beach, were commuting to areas of higher levels of pollutants. This was not the case since the majority of residents of both Glendora and Long Beach who commuted actually worked in areas with lower levels of pollutants[5]. On the other hand, the vast majority of the residents of the low pollution area, Lancaster, who commuted did so to areas of higher levels of pollutants. Thus, the observed commuting patterns would tend to bias the results in the direction of decreasing the probability of observing a difference between the three study areas.

G. Changes in Lung Function Test

1. Symptoms

The distribution of changes in symptoms are given in Tables 15 and 16 for never smokers and in Table 17 for smokers. These tables are set up to indicate the proportion of individuals without a specific symptom who developed that symptom and the proportion who had the symptom at baseline but did not reported it at retesting. The symptoms shown include cough, cough with sputum production, wheeze and diagnosis of asthma, bronchitis and emphysema.

The incidence of these symptoms tended to be greater among smokers than never smokers but there was no consistent relationship for either the development of new symptoms or the loss of symptoms among the three communities.

2. Lung function tests:

The lung function test results have been determined by taking the mean of the differences for each individual participant's baseline minus his/her retest value and converting it to an annual rate according to the formula:

$$\frac{T_1 - T_2}{\text{\# of mos. between } T_2 \text{ \& } T_1} \times 12$$

Thus, the results using this formula are independent of "expected" values. Although this formula may not eliminate problems of regression to the mean, this phenomenon should be present in each of the three communities tested and should, thus, not account for differences between communities.

The mean annual change in the spirometric indices and the single breath nitrogen test is shown in Table 18 for never smoking residents who were 7-24 years of age at baseline and in Table 19 for both smoking and never smoking individuals who were 25-59 years of age at baseline. Both tables are stratified by sex and specific test. Table 18 is subdivided into four age groups within the 7-24 year range and is limited to consideration of individuals who did not report smoking either at baseline or at retesting. (Smokers under 24 years of age were eliminated because of the problems with uncertainty in determining when smoking actually began in these residents who may have been responding to the questionnaire in the presence of one or both of their parents.) Table 19, for adults, is separated into individuals who never reported smoking and individuals who reported smoking at baseline regardless of whether they quit smoking between baseline testing and retesting. Table 20 shows the proportion of residents in the 25-59 age group who either quit smoking between baseline and retesting or who began smoking in that interval.

For each pulmonary function variable reported the mean for Lancaster was compared with the mean for Glendora and the mean for Long Beach using a multiple comparison test developed by Scheffe[28]. Effectively this implies that, in order to be labeled significant, differences must be somewhat greater than single comparison t-values.

Tables 21 and 22 show where results were observed which demonstrated a difference which was significant at $p < .05$ or $p < .01$ levels labeled according to sex, age groups and the lung function test administered.

A careful review of the changes in lung function (Table 18) for the young participants reveal some consistent patterns among the study areas. First, the changes in lung function test results for both males and females in the 19-24 age cohort show the smallest decline in the Lancaster cohort for each of the five lung function tests shown. Among the males the annual decline in each lung function measurement was greatest for the Long Beach cohort. The differences between the communities for females, although less than observed for males, were not consistently worse either in Long Beach or Glendora. Nine of the twenty-four comparisons with Lancaster were significantly more favorable for the Lancaster cohort, three compared to Glendora and six to Long Beach.

In the 7-10 age group, no consistent differences were observed between the cities except for $\Delta N_{2_{750-1250}}$ which was significantly more favorable for both males and females in Lancaster compared to both Glendora and Long Beach and for FEV_1 and FVC for females in Lancaster compared to Long Beach (Table 18).

In the 11-14 age group, there were no consistent differences in spirometric tests between the Lancaster and Glendora or Long Beach cohorts.
The $\Delta N_{2_{750-1250}}$ was significantly more favorable for the Lancaster cohort than for the Glendora cohort and females in Long Beach.

In the 15-18 age group there were again no consistent differences in spirometric results. Change in FVC was significantly more favorable for Lancaster females than in the other two areas and $\Delta N_{2_{750-1250}}$ was significantly better for all Lancaster participants except females in Long Beach.

Although smokers tended to decline at a greater rate than never smokers according to most tests, the differences in rate of decline were not as large as one might have expected. There are, however, several factors that could account for the apparently slower decline in smokers than would be expected. Many voluntary studies of communities have observed that sicker individuals tend not to volunteer for these types of studies[22]. We compared the lung function test results from individuals who were and were not retested according to smoking status[9,10]. That analysis revealed that a lower proportion of smokers with poor test results at baseline were retested than of never-smokers with poor test results. That is, a higher proportion of retested smokers had good test parameters at baseline than of retested never-smokers. Finally, we noted that a higher proportion of individuals had stopped smoking in the interval and this proportion was considerably higher among females in Glendora than in Lancaster (24% versus 13%). Thus, it is probable that the smokers who participated in the retesting were selected towards health and don't represent the general population of smokers.

With only two exceptions, in every pulmonary test the rate of change was more favorable among Lancaster adult residents than among adult residents in Long Beach or Glendora study areas. The two exceptions were FEV_1 and FVC for female smokers in which the rate of decline for the Glendora cohort was less than that of the Lancaster cohort but not significantly less. The proportion of females in the smoking group who gave up smoking, however, was almost twice as high in Glendora (23.7%) than in Lancaster (12.7%).

In 13 of the 24 comparisons of Glendora adults with Lancaster adults the mean change was significantly smaller in Lancaster (Tables 21,22). Nine of these were at the $p < .01$ level. In 17 of the 24 comparisons of Long Beach with Lancaster the mean change was significantly smaller in Lancaster. Twelve of these were at the $p < .01$ level.

An interesting observation is that the only test which appears to most consistently identify more favorable changes in lung function in the Lancaster cohort, compared to the other two cohorts, was $\Delta N_{2_{750-1250}}$ which was significantly more favorable even in the youngest age group (Tables 18, 19, 20). The pattern of differences for the other tests of lung function in the groups below 19 years of age at baseline is inconsistent. In the 19-24 year olds, however, the results were more favorable for all tests in the Lancaster cohort than in either of the other two cohorts although only a few differences were significant. In the oldest group, those 25-59 years of age at baseline, there are many significant differences between tests.

At least two interesting observations can be made on the basis of this observed consistency of differences in the group 19 years of age and above, and in the attaining of statistical significance in the oldest age group. One possibility is that physiologic impairment which is occurring in younger individuals do not become severe enough to demonstrate differences in lung function tests until early adulthood. This is not surprising since the period of most rapid growth in FEV_1 and FVC has been demonstrated to occur between 10 and 18 years of age which would have encompassed most of the younger participants in this study. The period of greatest variability in the rate of change in FEV_1 and FVC occurs between the ages of 18 and approximately 25.

Given these factors which would favor showing no differences between cohorts, it is surprising to observe the consistently more favorable rate of change in the $\Delta N_{2_{750-1250}}$ in all age groups despite the very large standard deviations for that test. The $\Delta N_{2_{750-1250}}$ has been suggested as a very sensitive test of small airways disease but has been subject to a great deal of variability[21]. Variability between participants would be a greater problem in cross-sectional studies than in cohort studies in which each individual is measured against themselves. This study suggests that perhaps that test is a reasonably sensitive indicator of lung damage in larger groups.

Of more interest to the present study, the early changes identified by the $\Delta N_{2_{750-1250}}$ may be occurring during the period of most rapid change in the lung in early life. Considerably more work needs to be done to confirm this interpretation of early impairment of lung function associated with exposure to air pollution. The possible validity of this observation is strengthened by the observation that by the time individuals have reached the 19-24 year age group, they are demonstrating consistent differences in favor of the low pollution cohort and that a great many statistically significant differences can be demonstrated in the 25-59 age group.

This in turn may explain our observation that the rate of change in FEV_1 is very gradual between 25-59 years of age in Los Angeles[6]. This is an artifact due to the fact that a higher proportion of older residents of Los Angeles actually migrated from other areas presumably exposed to lower levels of air pollution, than among the younger members of the cohort, a considerably higher proportion of whom have been raised in Los Angeles. Thus, the younger members of our cohort may experience even greater rates of decline as they age than we are currently observing in our older cohort members who, in fact, may have declined at a lower rate when they were younger. Again, this finding suggests that the long-term impact of chronic exposure to air pollution may be more than can be estimated from cross-sectional studies.

For each test in which a statistically significant difference was observed the rate of change was more favorable among the Lancaster cohort exposed to the lowest levels of pollutants. Generally, there were a greater number of tests and a higher level of significance observed among never smokers than among smokers. This difference was particularly apparent among the females. This may reflect the strong effect of smoking on rate of decline in lung function, reducing the probability of observing a statistically significant difference related to pollution.

A new finding, however, was the consistent pattern of a significantly more favorable change in $\Delta N_{2_{750-1250}}$ for all age sex groups in Lancaster compared to the other communities except for 19-24 year old males in both polluted areas and 15-18 year females and 11-14 year males in Long Beach. The magnitude of the change in $\Delta N_{2_{750-1250}}$ was consistently greater for the Glendora cohort than for the Long Beach or Lancaster cohort. This was interesting since there were a greater number of significant differences in spirometric tests between communities in the Long Beach cohort (35/60 comparison) than in to the Glendora cohort (23/60).

We looked for differences in individual tests between communities which might identify a specific test which was associated with one polluted area and not the other. None of the spirometric tests were consistently different from Lancaster in either polluted area. The $\Delta N_{2_{750-1250}}$ was more frequently significantly lower compared to Lancaster in Glendora (11 of 12 age, sex, smoking specific groups) than in Long Beach (9 of 12 groups). The magnitude of the different frequency was, however, small.

H. Departures From Original Work Plan

There were two departures made from the original work plan. We did a second reexamination of participants in the Burbank area (1982) and in the Long Beach area (1983). In each instance, the period of retesting covered a period in four to six weeks in which participants who were willing to be reexamined on one invitation were retested. Most of those retested were retested in a period of lower exposure to air pollutants than when they were retested at baseline and first retesting. In addition, those who were retested were observed to have had better test results at baseline and a lesser rate of decline than the cohort as a whole. The proportion who were retested represented about one-third of the cohort completing retesting a second time. The results in the "grab bag" sample retested a second time were not compatible with the results of retesting the second time. Because of the non-random nature of the cohort, the tendency of the more healthy individuals to volunteer and the short interval between the time of second testing and the time of third testing it was decided not to adjust the results of the first retesting by consideration of the smaller sample of individuals retested a second time.

I. Future Analyses

A proposal for further analyses has been submitted which includes 1) a more detailed analysis of resident's air pollution exposures; 2) application of multivariate models for further exploration of the association of measures of respiratory diseases with the more detailed estimates of cumulative air pollution exposure; 3) examination of specific subgroups which may be more sensitive to effects of air pollutants; 4) grouping of tests to see if enhanced specificity can be obtained thereby; and 5) comparison of rates of changes in lung function taking into account history of residence in areas of heavy pollution especially in early life. A copy of the proposed analysis is included in Appendix 15.

J. Conclusions

There were a number of problems associated with this study from which most cohort studies of large populations suffer. The two major problems were the relatively low response rate of the cohort overall and the opportunity to retest the entire cohort only twice over a five to six year interval. Nonetheless, comparison of baseline results among those who completed testing and those who did not, indicate that there were only small differences between those retested and those not retested, probably because the majority of those not retested were not refusals but were individuals who moved out of the study area before retesting took place. The distribution of the major confounders among the three study populations was such that the differences observed are more likely to be an underestimate of true differences that would have occurred in the absence of these confounders.

The change in reported symptoms was not found to correlate with pollutant exposure and varied widely. These results suggest that reported symptoms may be too non-specific to be of much use in studies of this nature.

Despite these problems, the results of spirometry and the single breath nitrogen test can still be cautiously interpreted as showing a more favorable rate of change among participants in the less polluted area than in the more polluted areas. In fact, in every instance in which there was a statistically significant difference in the rate of change, that change was more favorable in the less polluted area.

A disturbing observation in our studies was the magnitude of the rate of decline among adults, even in the control area. The annualized decline in FEV_1 was considerably higher than has been reported by most investigators except for a few reports in occupational groups[20-27]. A possible reason for this which must be considered is that there was a fixed error in the mobile lung function test equipment which tended to result in exaggerated rates of decline. The results of lung function testing in the mobile lung function laboratory were, however, somewhat low compared to the values observed in the same individuals retested at the UCLA laboratory, both at baseline and at re-testing but the magnitude of the differences annualized over the test-retest interval were small. A second explanation which must be considered is the possibility that individuals chronically exposed to the levels of pollutants observed in both our control and study areas may be suffering from greater rates in decline of FEV_1 than the cohorts reported from other study areas and studies which were subject to lower levels of air pollutants than our control area. This possibility should be investigated further.

A particularly interesting observation from this study is the consistently less favorable rates of change observed in $\Delta N_{2_{750-1250}}$ in children in the study areas chronically exposed to high levels of air pollutants. The possibility that the $\Delta N_{2_{750-1250}}$ may identify early physiologic changes recognized only later using spirometric tests should be further considered. The greatest changes in the lung occur during the early years of life and, thus, it is not unreasonable to be concerned that chronic exposure to air pollutants during this important stage of growth and development of the lung may represent exposure during a period of greatest susceptibility. This can be investigated by comparing children who were born and raised in the areas of highest air pollution to children who were born and raised in areas exposed to lower levels of air pollutants.

K. Publications

Below are a listing of publications which have either appeared in print during the period of support by the California Air Resources Board, have been accepted for publication or are in the process of being submitted. Copies of the published papers and of the manuscripts accepted for publication are enclosed in the Appendix.

Detels, R., Rokaw, S, Coulson A, Tashkin, D, Sayre, J and Massey, F: The UCLA Population Studies of Chronic Obstructive Respiratory Disease. I. Methodology and comparison of lung function in areas of high and low pollution. Amer. J. Epid. 109/1:33-58, 1979.

Tashkin, D., Detels, R, Coulson, A, Rokaw, S: The UCLA Population Studies of Chronic Obstructive Respiratory Disease. II. Determination of reliability and estimation of sensitivity and specificity. Envir. Res. 20:403-424, 1979.

Rokaw, S, Detels, R, Coulson, A, Sayre, J, Tashkin, D, Allwright, S, Massey F: The UCLA Population Studies of Chronic Obstructive Respiratory Disease. III. Comparison of pulmonary function in three communities exposed to photochemical oxidants, multiple primary pollutants or minimal pollutants. CHEST 78:252-262, 1980.

Detels, R, Sayre, J, Coulson, A, Rokaw, S, Massey, F, Tashkin, D, Wu, M: Respiratory effect of long-term exposure to two mixes of air pollutants in Los Angeles County. CHEST 80S-27S-29S, July 1981 suppl.

Detels, R, Sayre, J, Coulson, A, Rokaw, S, Massey, F, Tashkin, D, Wu, M: The UCLA Population Studies of Chronic Obstructive Respiratory Disease. IV. Respiratory effect of long-term exposure to photochemical oxidants, nitrogen dioxide, and sulfates on current and never smokers. Amer. Rev. Respir. Dis. 124:673-680, 1981.

Detels, R, Tashkin, D, Simmons, M, Carmichael, H, Sayre, J, Rokaw, S, Coulson, A: The UCLA Population Studies of Chronic Obstructive Respiratory Disease. V. Agreement and disagreement of tests in identifying abnormal lung function. CHEST 82/5:630-638, 1982.

Tashkin, D, Clark, V, Coulson, A, Bourque, L, Simmons, M, Detels, R, Rokaw, S: Comparison of lung function in young smokers and non-smokers before and after initiation of the smoking habit: A prospective study. Am. Rev. Respir. Dis. 128:12-16, 1983.

Detels, R, Sayre, J, Tashkin, D, Massey, F, Coulson, A, Rokaw, S: The UCLA Population Studies of Chronic Obstructive Respiratory Disease. VI. Relationship of physiologic factors to rate of change in FEV_1 and FVC. Am. Rev. Respir. Dis. 129:533-537, 1984.

Tashkin, D, Clark, V, Simmons, M, Reems, C, Coulson, A, Bourque, L, Sayre, J, Detels, R, Rokaw, S: The UCLA Population Studies of Chronic Obstructive Respiratory Disease. VII. Relationship between parental smoking and children's lung function. Am. Rev. Respir. Dis. 129:891-897, 1984.

Tashkin, P, Clark, V, Coulson, A, Simmons, M, Bourque, L, Reems, C, Detels, R, Sayre, J, Rokaw, S: The UCLA Population Studies of Chronic Obstructive Respiratory Disease, VIII. Effects of Smoking Cessation on Lung Function: A Prospective Study of Free-Living Population. Am. Rev. Respir. Dis. 130/5:707-715, 1984.

IV. INVESTIGATIVE STAFF

Responsibility for the project was divided into the following areas: a) overall direction, b) recruitment of study subjects, c) operation of field laboratory, d) operation of the UCLA validation laboratory, e) coordination of the data from the household roster, field laboratory, and validation laboratory, f) collection of air pollutant and meterologic variables, g) data management, and h) data analysis. Each area was the primary responsibility of one of the investigators, but there was considerable overlap with individual investigators providing input to several areas.

(a) Roger Detels, MD, MS, was the Principal Investigator and was responsible for the overall direction of all components of the study.

(b) Jan Dudley, MPH, the field coordinator was responsible for recruitment of the members of the cohort and for direction of the neighborhood representatives. She worked directly under Dr. Detels.

(c) The Mobile Lung Research Laboratory of the American Lung Association of Los Angeles County which made the field measurements of lung function was under the direction of Stanley Rokaw, MD, Clinical Professor of Medicine. He directed the technical staff of the laboratory including the laboratory supervisor and the three technicians.

(d) The validation laboratory was under the direction of Donald Tashkin, MD, Professor of Medicine and Director of the UCLA Pulmonary Function Laboratory. Dr. Tashkin directed the laboratory technician in the re-examination of the 3% probability sample who were retested at UCLA. In addition, Dr. Tashkin and Dr. Rokaw shared jointly the responsibility for overseeing immediate retesting, seasonal retesting, and the other validation procedures necessary to assure that the field laboratory was not subject to drift or other fixed errors and for interpretation of lung function test results.

(e) Janice Dudley was responsible for the coordination of data from the household rosters, the field laboratory, and validation laboratory. She worked directly with Drs. Rokaw, Tashkin, Sayre and Detels.

(f) Measurement of pollutants obtained at the monitoring stations of the Southern California Air Resources Board. Mr. Dane Westerdahl and Dr. Stanley Dawson kindly took responsibility for seeing that we obtained the tapes of these measurements. In addition, the California Air Resources Board coordinated the efforts of other investigators in the area of air pollution to assure that we were aware of all activities which related to our project, including estimates of pollutant exposures derived from other techniques such as isopleth studies.

(g) All data management aspects of the study were under the direction of Dr. James Sayre. He directed the statistical/computer staff who reviewed the data received from the field laboratory, the validation laboratory and the neighborhood representatives for accuracy and entered it into the base files. Dr. Sayre worked closely with Frank Massey, Jr., Professor of Biostatistics, and Dr. Detels.

(h) Dr. Frank Massey, Jr. had primary responsibility for data analysis. However, data analysis techniques and approaches were discussed at the joint weekly meetings held by the investigative staff (Detels, Rokaw, Massey, Sayre, Tashkin, Coulson, Dudley) and different aspects were looked at intensively by the appropriate investigator(s).

(i) In the final year Professor David Wegman, formerly at Harvard and an expert in occupational respiratory disorders joined the investigative staff.

In summary, this was a joint project supported by investigators from the Divisions of Epidemiology and Biostatistics in the School of Public Health, the Department of Medicine in the School of Medicine, the American Lung Association of Los Angeles County, and the Research Bureau of the California Air Resources Board.

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Table 1. Demographic Characteristics of Study Census Tracts in Burbank, Lancaster, Long Beach & Glendora*

Characteristics	Burbank	Lancaster	Long Beach	Glendora
Total residents, all ages	6,848	7,069	4,992	4,573
White (non-Spanish surnamed)	6.022 (87.8%)	6,430 (90.9%)	4,939 (98.9%)	4,281 (93.6%)
Spanish-surnamed	744 (11.0%)	434 (6.1%)	0 (0.0%)	162 (3.5%)
Black	9 (0.1%)	91 (1.3%)	3 (0.1%)	3 (0.1%)
Other	73 (1.1%)	114 (1.6%)	50 (1.0%)	127 (2.8%)
Total 7+ years of age	6,170	6,121	4,691	4,061
Median income	$11,502	$11,631	$11,474	$12,746
Number of housing units	2,422	2,238	2,197	1,611
Proportion of homeowners	72%	63%	64%	61%
Median home value	$23,000	$18,600	$23,400	$23,850

*According to the 1970 Census

Table 2. Number, Proportion, and Characteristics of Residents Completing Baseline Lung Function Testing in Burbank, Lancaster, Long Beach and Glendora

	Burbank		Lancaster		Long Beach		Glendora	
Households occupied	2,241		2,551		2,645		2,629	
Households enumerated	2,034	(91%)	2,143	(84%)	2,514	(95%)	2,596	(98%)
Residents enumerated:	4,968		5,722		5,007		4,809	
Completed testing	3,465	(70%)	4,509	(79%)	3,786	(76%)	3,403	(71%)
Completed questionnaire only	63	(1%)	79	(1%)	405	(8%)	374	(8%)
Not tested	1,440	(29%)	1,134	(20%)	816	(16%)	1,008	(21%)
Characteristics of residents completing testing								
White: Male	1,541	(44%)	2,085	(46%)	1,668	(44%)	1,535	(45%)
Female	1,710	(49%)	2,186	(48%)	1,987	(52%)	1,721	(51%)
Spanish-surnamed: Male	88	(3%)	59	(1%)	33	(1%)	45	(1%)
Female	99	(3%)	50	(1%)	48	(1%)	70	(2%)
Black: Male	0	(0%)	41	(1%)	3	(<1%)	2	(<1%)
Female	1	(<1%)	46	(1%)	17	(<1%)	2	(<1%)
Other: Male	17	(<1%)	17	(<1%)	14	(<1%)	11	(<1%)
Female	9	(<1%)	25	(<1%)	16	(<1%)	11	(<1%)
TOTALS:	3,465	(100%)	4,509	(100%)	3,786	(100%)	3,403	(100%)
Total Males	1,599	(48%)	2,202	(49%)	1,718	(45%)	1,599	(47%)
Total Females	1,816	(52%)	2,307	(51%)	2,068	(55%)	1,804	(53%)

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Table 3. Annual Means of Daily Maximum Hourly Average (or 24-Hour Totals) of Pollutants in Lancaster (LN), Long Beach (LB), and Glendora (GL)

Pollutant	City	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982*
SO_2 (ppm) ¶	LN	.01	+	.01	.01	.01	.00	.00	.01	.01	.00	.00
	LB	.07	.04	.04	.05	.04	.04	.04	.03	.03	.03	.03
	GL	.03	.03	.02	.02	.02	.02	.02	.02	.01	.01	.01
Oxidants (ppm) Φ	LN	.06	.07	.06	.06	.07	.06	.06	.08	.08	.08	.07
	LB	.04	.04	.04	.03	.03	.04	.04	.05	.05	.05	.04
	GL	.11	.10	.12	.11	.11	.11	.12	.12	.11	.11	.10
NOx(ppm) Ψ	LN	.08	.08	.08	.08	.10	.09	.10	.10	.08	.07	.06
	LB	.36	.31	.27	.23	.31	.29	.29	.28	.18	.21	.20
	GL	.18	.17	.17	.18	.18	.21	.20	.14	.12	.14	.13
NO(ppm)	LN	.06	.05	.06	.05	.07	.06	.06	.07	.05	.04	.03
	LB	.26	.22	.18	.15	.21	.19	.20	.19	.12	.14	.14
	GL	.10	.08	.08	.10	.10	.12	.11	.08	.07	.07	.07
NO_2(ppm)	LN	.03	.02	.03	.04	.03	.04	.04	.04	.03	.03	.03
	LB	.13	.11	.12	.11	.13	.12	.11	.12	.08	.10	.09
	GL	.11	.10	.12	.11	.10	.12	.12	.08	.07	.08	.08
SO_4($\mu g/m^3$)**	LN	+	+	+	3.5	+	4.0	4.5	5.1	4.6	4.3	4.2
	LB	+	+	+	12.2	+	12.1	10.7	10.9	13.0	12.1	9.4
	GL	+	+	+	11.0	+	13.4	10.8	10.0	10.2	10.0	8.7
Particulates** ($\mu g/m^3$)	LN	108	99	80	79	74	93	75	94	103	74	59
	LB	94	77	104	113	119	111	102	103	106	109	76
	GL	166	143	119	126	119	168	141	118	128	134	97

* 1982 values were calculated from the months Jan.-Sept. only

\+ data not available

¶ Methods of calculation not the same over time or between cities

Φ Beginning in 1979, values are for ozone.

Ψ Beginning in Jan. 1980, method of calibration changed - new method produces values lower than those produced by old method

** 24 hour totals

TABLE 4

Prediction Equations * for Spirometry Derived from Burbank Normals **
(Split Samples)

Sex	Age group	N	Prediction equation	S.E. of estimate	Mult. R.
Male	7-17	103	E (FVC) = — 2084 + 142 (Age) + 33 (Ht) + 14 (Wt)	SE (FVC) = 418	.94
			E (FEV) = — 2082 + 115 (Age) + 35 (Ht) + 12 (Wt)	SE (FEV) = 352	.95
			E (FEF 25) = — 7026 + 32 (Wt) + 519 (Sheldon)	SE (FEF 25) = 837	.81
			E (FEF 50) = — 6000 + 26 (Wt) + 438 (Sheldon)	SE (FEF 50) = 783	.77
	18-59	258	E (FVC) = — 3536 — 23 (Age) + 131 (Ht)	SE (FVC) = 604	.66
			E (FEV) = — 3213 — 29 (Age) + 119 (Ht)	SE (FEV) = 522	.73
			E (FEF 25) = — 2623 — 43 (Age) + 126 (Ht)	SE (FEF 25) = 1149	.52
			E (FEF 50) = — 2300 — 41 (Age) + 104 (Ht)	SE (FEF 50) = 942	.56
	60+	81	E (FVC) = — 2791 — 25 (Age) + 119 (Ht)	SE (FVC) = 499	.66
			E (FEV) = — 3202 + 90 (Ht)	SE (FEV) = 498	.49
			E (FEF 25) = 1085 + 8 (Wt)	SE (FEF 25) = 1100	.18
			E (FEF 50) = 1328 + 5 (Wt)	SE (FEF 50) = 828	.17
Female	7-17	102	E (FVC) = — 1399 + 63 (Age) + 93 (Ht) — 167 (Sheldon)	SE (FVC) = 330	.91
			E (FEV) = — 3618 + 72 (Age) + 87 (Ht)	SE (FEV) = 272	.93
			E (FEF 25) = — 4807 + 113 (Age) + 111 (Ht)	SE (FEF 25) = 704	.80
			E (FEF 50) = — 3961 + 82 (Age) + 93 (Ht)	SE (FEF 50) = 642	.76
	18-59	269	E (FVC) = — 3675 — 19 (Age) + 121 (Ht)	SE (FVC) = 491	.68
			E (FEV) = — 1917 — 22 (Age) + 105 (Ht) — 89 (Sheldon)	SE (FEV) = 378	.75
			E (FEF 25) = 1255 — 35 (Age) + 102 (Ht) — 238 (Sheldon)	SE (FEF 25) = 913	.51
			E (FEF 50) = 1174 — 33 (Age) + 76 (Ht) — 170 (Sheldon)	SE (FEF 50) = 810	.50
	60+	64	E (FVC) = — 642 — 31 (Age) + 81 (Ht)	SE (FVC) = 399	.61
			E (FEV) = 340 — 29 (Age) + 57 (Ht)	SE (FEV) = 352	.58
			E (FEF 25) = 5132 — 45 (Age)	SE (FEF 25) = 774	.33
			E (FEF 50) = 3804 — 34 (Age)	SE (FEF 50) = 673	.29

* Predictions : Age in yrs, Height in inches, Weight in lbs, Sheldon index computed as Ht $\sqrt[3]{Wt}$.

** Non smokers with no positive responses to symptom questions or history of respiratory disease.

Table 5

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AVERAGE ANNUAL CHANGE IN RESIDENTS 25-59 YEARS IN FOUR STUDY AREAS

	Burbank	Lancaster	Long Beach	Glendora
MALES : Smokers				
FEV_1 (ml)	- 31	- 54	- 78	- 70
FVC (ml)	+ 9	- 55	- 97	- 83
FEF_{25-75} (ml/sec)	-101	- 81	-122	-113
: Never Smokers				
FEV_1	- 29	- 50	- 65	- 56
FVC	- 4	- 56	- 82	- 71
FEF_{25-75}	- 66	- 51	- 93	- 95
FEMALES : Smokers				
FEV_1	- 23	- 48	- 54	- 45
FVC	- 7	- 57	- 57	- 51
FEF_{25-75}	- 68	- 57	- 99	- 82
: Never Smokers				
FEV_1	- 20	- 36	- 50	- 47
FVC	- 6	- 41	- 60	- 47
FEF_{25-75}	- 51	- 56	- 79	-100

5/29/84

Table 6. Comparison of Mean of Differences in FEV_1 in Participants Whose Baseline FEV_1 was Greater than 75% (O/E) Testedat the Mobile Laboratory and the UCLA Laboratory at Baseline and Retesting

MEAN DIFFERENCE (Mobile UCLA Lab)	LANCASTER	BURBANK	GLENDORA	LONG BEACH
FEV_1				
Baseline (T_1)	$-80^{\pm 30}$ cc* (N=76)	$-190^{\pm 40}$cc (N=38)	$-80^{\pm 30}$cc (N=77)	$-140^{\pm 60}$cc (N=51)
Retest (T_2)	$-70^{\pm 110}$cc (N=9)	$+40^{\pm 60}$cc (N=35)	$-120^{\pm 40}$cc (N=33)	$-60^{\pm 250}$cc (N=9)
$T_1 - T_2$	-10 cc	-230 cc	-40 cc	-80 cc

* Standard error of mean .

N.B. A minus value suggests that the observed $T_1 - T_2$ value in the mobile laboratory is an underestimate of the actual $T_1 - T_2$, where as a positive value suggests that the observed $T_1 - T_2$ value is an overestimate . T_1-T_2 equals 5 years in Lancaster, Burbank and Glendora and 6 years in Long Beach.

Table 7. Annualized Mean Changes in FEV_1, FVC, FEF_{25-75} and $\Delta N_{2\,25-75}$ between Baseline (T_1) and Two Retests (T_2 & T_3) in Persons Tested All Three Times in Burbank Volunteers

	$T_2 - T_1$	$T_3 - T_1$	$T_3 - T_2$
MALES : Smokers			
FEV_1 (ml)	- 29	- 53	- 79
FVC (ml)	+ 18	- 34	- 90
FEF_{25-75} (ml/sec)	-108	-123	-138
$\Delta N_{2\,750-1250}$ (%)	-.008	+.046	+.105
: Never Smokers			
FEV_1 (ml)	- 38	- 45	- 54
FVC (ml)	- 11	- 43	- 79
FEF_{25-75} (ml/sec)	- 64	- 73	- 81
$\Delta N_{2\,750-1250}$ (%)	-.022	+.023	+.074
FEMALES : Smokers			
FEV_1 (ml)	- 21	- 36	- 52
FVC (ml)	+ 2	- 28	- 60
FEF_{25-75} (ml/sec)	- 78	- 85	- 92
$\Delta N_{2\,750-1250}$	-.010	+.066	+.152
: Never Smokers			
FEV_1 (ml)	- 16	- 35	- 57
FVC (ml)	- 4	- 35	- 68
FEF_{25-75} (ml/sec)	- 42	- 65	- 90
$\Delta N_{2\,750-1250}$	-.023	+.029	+.088

Table 8. Retest Status of Cohorts[+]

RESIDENCE AT BASELINE/ RESIDENCE AT RETEST	RESPONDENTS				NON-RESPONDENTS		TOTAL
	LFT*	Quest. Only	Deaths	Subtotal	Refused	Lost	
LANCASTER							
Study Area	1148 (72%)	101 (6%)	30 (2%)	1279 (80%)	323 (20%)	-	1602
Moved	39 (5%)	300 (37%)	6 (1%)	345 (42%)	-	467 (58%)	812
Subtotal	1187 (49%)			1624 (67%)			2414
GLENDORA							
Study Area	1050 (79%)	33 (2%)	19 (1%)	1102 (83%)	226 (17%)	-	1328
Moved	89 (14%)	163 (27%)	2 (<1%)	254 (41%)	-	360 (59%)	614
Subtotal	1139 (59%)			1356 (70%)			1942
LONG BEACH							
Study Area	737 (74%)	98 (10%)	36 (3%)	871 (87%)	128 (13%)	-	999
Moved	84 (11%)	176 (22%)	2 (<1%)	262 (33%)	-	538 (67%)	800
Subtotal	821 (46%)			1133 (63%)			1799

+ 25-59 years of age at T_1

* Lung function tests

Table 9a. Proportion Retested* Stratified by Age, Sex, Smoking Status, and Place of Residence

	Current Smokers				Never Smokers			
	Lancaster		Glendora		Lancaster		Glendora	
Sex/Age(yr)	Tested at Baseline	Percent Retested	Tested at Baseline	Percent Retested	Tested at Baseline	Percent Retested	Tested at Baseline	Percent Retested
Males								
7-10	–	–	–	–	210	50	141	65
11-14	–	–	–	–	217	47	137	59
15-18	–	–	–	–	140	26	93	49
19-24	–	–	–	–	61	38	74	46
25-39	178	40	130	48	138	51	143	55
40-59	204	48	111	64	124	58	104	69
Females								
7-10	–	–	–	–	162	46	140	65
11-14	–	–	–	–	207	51	138	62
15-18	–	–	–	–	158	35	103	47
19-24	–	–	–	–	82	37	97	47
25-39	165	44	108	53	229	54	260	63
40-59	188	41	128	58	253	55	181	70

*White only; 7-59 years of age at baseline; had not changed job or residence because of a respiratory problem; FEV_1 exists at both times.

Table 9b. PROPORTION RETESTED* STRATIFIED BY AGE, SEX, SMOKING STATUS, AND PLACE OF RESIDENCE

	Current Smokers				Never Smokers			
	Lancaster		Long Beach		Lancaster		Long Beach	
Sex/Age (yr)	Tested at Baseline	Percent Retested	Tested at Baseline	Percent Retested	Tested at Baseline	Percent Retested	Tested at Baseline	Percent Retested
Males								
7-10	--	--	--	--	210	50	87	40
11-14	--	--	--	--	217	47	67	27
15-18	--	--	--	--	140	26	50	32
19-24	--	--	--	--	61	38	63	38
25-39	178	40	147	34	138	51	141	48
40-59	204	48	130	41	124	58	97	60
Females								
7-10	--	--	--	--	162	46	77	44
11-14	--	--	--	--	207	51	73	36
15-18	--	--	--	--	158	35	52	39
19-24	--	--	--	--	82	37	89	42
25-39	165	44	117	35	229	54	193	42
40-59	188	41	161	46	253	55	208	54

* White only, 7-59 yr of age at baseline; had not changed job or residence because of a respiratory problem; FEV_1 exists at both times

Table 10. Response Rate at Retest** According to Baseline FEV_1 Results in Lancaster, Long Beach, Burbank, and Glendora

SEX/RESIDENCE	FEV_1 AT BASELINE	
	< 75% O/E	≥ 75% O/E
Smokers		
Males		
Lancaster	50% (30)*	48% (352)
Glendora	54% (28)	57% (213)
Long Beach	40% (15)	41% (235)
Females		
Lancaster	40% (40)	47% (313)
Glendora	57% (28)	56% (205)
Long Beach	46% (28)	48% (215)
Never-Smokers		
Males		
Lancaster	57% (7)	57% (255)
Glendora	50% (4)	63% (243)
Long Beach	80% (5)	55% (216)
Females		
Lancaster	33% (12)	61% (470)
Glendora	73% (11)	67% (429)
Long Beach	46% (11)	54% (361)

* Number in group at baseline testing

** White only; 25-59 years of age at T_1 ; did not change job or residence because of a lung problem; FEV_1 exists at both times.

Table 11a. MEAN % FEV_1 (O/E) AT BASELINE AMONG THOSE RETESTED, THOSE NOT RETEST, AND THOSE WHO HAD DIED*

Residence/Retest Status	Number	Mean % FEV_1 (O/E)† ± Standard Error
Lancaster		
Retested	1815	100.0 ± 0.4
Died	35	91.3 ± 3.3
Not retested	2063	99.0 ± 0.4
Questionnaire only	639	99.3 ± 0.7
Refused	480	96.5 ± 0.6
Lost	944	100.0 ± 0.5
Long Beach		
Rested	1051	102.5 ± 0.5
Died	33	89.1 ± 4.5
Not retested	1222	100.5 ± 0.5
Questionnaire only	326	102.8 ± 1.0
Refused	132	95.5 ± 1.5
Lost	764	100.5 ± 0.6

* White only; 7-59 yr of age at T_1; had not changed job or residence because of a respiratory problem

† Expected values derived from previously reported equations

Table 11b. Mean FEV_1 (O/E) at Baseline Among Those Retested, Those Not Retested, and Those Who Had Died*

Residence/Retest Status	Number	Mean FEV_1 (O/E)† ± Standard Error
Lancaster		
Retested	1815	100.0 ± 0.4
Died	35	91.3 ± 3.3
Not retested	2063	99.0 ± 0.4
Questionnaire only	639	99.3 ± 0.7
Refused	480	96.5 ± 0.6
Lost	944	100.0 ± 0.5
Glendora		
Retested	1681	100.4 ± 0.4
Died	22	88.8 ± 3.5
Not retested	1275	99.7 ± 0.4
Questionnaire only	379	99.5 ± 0.8
Refused	258	98.7 ± 1.0
Lost	638	100.3 ± 0.6

*White only; 7-59 years of age at T_1; had not changed job or residence because of a respiratory problem.

†Expected values derived from previously reported equations

Table 12. Correlation* Between (O/E%) FEV_1 and Level of Pollutant at Time of Retesting

	O_3	NO_2	SO_4	Particulates	SO_2
LANCASTER**					
Never Smokers					
Male	.03	-.01	.02	.09	+
Female	.05	.07	.10	.30	+
Smokers					
Male	-.13	.05	.09	.31	+
Female	.07	.01	.19	.16	+
LONG BEACH					
Never Smokers					
Male	.20	-.01	.12	.25	.07
Female	.10	-.06	-.05	.15	.02
Smokers					
Male	.25	.02	-.08	.26	-.08
Female	.25	-.20	.29	.37	-.03
GLENDORA					
Never Smokers					
Male	-.02	.05	-.05	.00	.06
Female	.10	.08	-.10	.04	.06
Smokers					
Male	.10	.09	-.13	-.07	.00
Female	-.10	.06	-.13	-.04	.07

* Correlation coefficient (at retest)

** White only; 25-59 years of age at T_1; did not change job or residence because of a lung problem; FEV_1 exists at both times.

\+ SO_2 not measured in Lancaster

Table 13. Mean Age and Height of Participants** 25-59 Years Old Who Were Retested

CHARACTERISTIC	STUDY AREA		
	Lancaster	Glendora	Long Beach
AGE			
Never Smokers:			
Male - mean	41±10 *	40±10	40±11
Female - mean	40±10	39±10	43±12
Smokers:			
Male - mean	42±10	42±10	42±11
Female - mean	41± 9	41± 9	44±10
HEIGHT			
Never Smokers:			
Male - mean	69± 3	69± 3	70± 3
Female - mean	64± 2	64± 2	64± 3
Smokers:			
Male - mean	69± 3	69± 3	69± 3
Female - mean	64± 2	64± 2	64± 2

* Mean age (or height) at baseline ± standard deviation

** White only; 25-59 years of age at T_1; did not change job or residence because of a lung problem; FEV_1 exists at both times

Table 14. Type of Heating Fuel Used in Study Areas

Type of Heating Fuel	Lancaster	Glendora	Long Beach
Gas	765 (94%)	760 (97%)	777 (94%)
Oil	11 (1%)	0	2 (<1%)
Electricity	34 (4%)	15 (2%)	45 (5%)
Other	5 (1%)	5 (1%)	3 (<1%)
TOTAL:	815	780	827

Table 15. Incidence of Losing and Developing Symptoms in the Interval Between Testing and Retesting in Never Smokers 7-24 Years Old*

Sex/Symptom/Residence	Incidence of Developing Symptom**		Incidence of Losing Symptom+	
MALES				
Cough				
Lancaster	30/256	(12%)	7/8	(88%)
Long Beach	4/87	(5%)	4/4	(100%)
Glendora	13/229	(6%)	18/21	(86%)
Cough & Sputum				
Lancaster	26/258	(10%)	6/6	(100%)
Long Beach	3/91	(3%)	0/0	(-)
Glendora	9/237	(4%)	10/12	(83%)
Wheezing				
Lancaster	24/226	(11%)	23/38	(60%)
Long Beach	4/71	(6%)	12/20	(60%)
Glendora	26/190	(14%)	27/60	(45%)
Asthma, Bronchitis & Emphysema				
Lancaster	3/240	(1%)	8/24	(33%)
Long Beach	3/79	(4%)	2/12	(17%)
Glendora	7/224	(3%)	6/26	(23%)
FEMALES				
Cough				
Lancaster	23/262	(9%)	4/4	(100%)
Long Beach	11/114	(10%)	2/2	(100%)
Glendora	21/246	(9%)	20/24	(83%)
Cough & Sputum				
Lancaster	18/262	(7%)	3/4	(75%)
Long Beach	7/113	(6%)	3/3	(100%)
Glendora	10/261	(4%)	7/8	(88%)
Wheezing				
Lancaster	18/241	(8%)	14/25	(56%)
Long Beach	13/102	(13%)	7/14	(50%)
Glendora	30/217	(14%)	27/53	(51%)
Asthma, Bronchitis & Emphysema				
Lancaster	13/255	(5%)	5/11	(46%)
Long Beach	2/103	(2%)	5/13	(39%)
Glendora	5/242	(2%)	7/28	(25%)

**New symptom divided by symptom not reported at baseline.

+Lost symptom divided by symptom reported at baseline.

*White only,

Table 16. Incidence of Losing and Developing Symptoms in the Interval Between Testing and Retesting in Never Smokers 25-29 Years Old*

Sex/Symptom/Residence	Incidence of Developing Symptom**		Incidence of Losing Symptom†	
MALES				
Cough				
Lancaster	18/142	(13%)	0/0	(-)
Long Beach	14/122	(12%)	1/2	(50%)
Glendora	13/141	(9%)	3/6	(50%)
Cough & Sputum				
Lancaster	17/140	(12%)	1/2	(50%)
Long Beach	10/123	(8%)	0/1	(0%)
Glendora	4/140	(3%)	5/7	(71%)
Wheezing				
Lancaster	17/130	(13%)	7/12	(58%)
Long Beach	10/113	(9%)	6/11	(54%)
Glendora	10/125	(8%)	15/22	(68%)
Asthma, Bronchitis & Emphysema				
Lancaster	1/133	(1%)	2/9	(22%)
Long Beach	4/114	(4%)	1/10	(10%)
Glendora	2/141	(1%)	1/6	(17%)
FEMALES				
Cough				
Lancaster	25/244	(10%)	6/19	(32%)
Long Beach	22/186	(12%)	1/6	(17%)
Glendora	33/267	(12%)	16/24	(67%)
Cough & Sputum				
Lancaster	21/253	(8%)	6/10	(60%)
Long Beach	11/187	(6%)	3/5	(60%)
Glendora	13/278	(5%)	9/13	(69%)
Wheezing				
Lancaster	12/233	(5%)	11/30	(37%)
Long Beach	11/173	(6%)	11/19	(58%)
Glendora	18/241	(8%)	31/50	(62%)
Asthma, Bronchitis & Emphysema				
Lancaster	10/245	(4%)	4/18	(22%)
Long Beach	6/180	(3%)	4/12	(33%)
Glendora	15/273	(6%)	5/17	(29%)

**New symptom divided by symptom not reported at baseline.

†Lost symptom divided by symptom reported at baseline.

*White only, did not change job or residence because of a lung problem; FEV_1 exists at both times.

Table 17. Incidence of Losing and Developing Symptoms in the Interval Between Testing and Retesting in Smokers 25-59 Years Old*

Sex/Symptom/Residence	Incidence of Developing Symptom**		Incidence of Losing Symptom+	
MALES				
Cough				
Lancaster	32/130	(25%)	14/39	(36%)
Long Beach	21/84	(25%)	6/17	(35%)
Glendora	21/93	(23%)	15/40	(38%)
Cough & Sputum				
Lancaster	25/140	(18%)	10/29	(34%)
Long Beach	14/89	(16%)	5/12	(42%)
Glendora	18/103	(18%)	14/30	(47%)
Wheezing				
Lancaster	19/125	(15%)	21/44	(48%)
Long Beach	14/66	(21%)	22/35	(63%)
Glendora	16/79	(20%)	18/54	(33%)
Asthma, Bronchitis & Emphysema				
Lancaster	14/148	(10%)	8/21	(38%)
Long Beach	4/88	(4%)	2/13	(15%)
Glendora	9/122	(7%)	2/11	(18%)
FEMALES				
Cough				
Lancaster	31/120	(26%)	8/31	(26%)
Long Beach	29/94	(31%)	6/20	(30%)
Glendora	16/98	(16%)	21/33	(64%)
Cough & Sputum				
Lancaster	33/131	(25%)	8/20	(40%)
Long Beach	21/102	(21%)	6/12	(50%)
Glendora	12/108	(11%)	14/22	(64%)
Wheezing				
Lancaster	17/110	(16%)	14/41	(34%)
Long Beach	10/69	(14%)	21/45	(47%)
Glendora	16/81	(20%)	25/50	(50%)
Asthma, Bronchitis & Emphysema				
Lancaster	13/130	(10%)	3/21	(14%)
Long Beach	9/94	(10%)	8/20	(40%)
Glendora	7/112	(6%)	4/19	(21%)

**New symptom divided by symptom not reported at baseline.

+Lost symptom divided by symptom reported at baseline.

*White only, did not change job or residence because of a lung problem; FEV_1 exists at both times.

Table 18 Mean Annual Change in Spirometric Indices in Residents[+] 7-24 Years Who Never Smoked

Sex/Age/Area	FEV_1 (ml)	FVC (ml)	FEF_{25-75} (ml/sec)	$\dot{V}_{75}$ (ml/sec)	$\dot{V}_{50}$ (ml/sec)	ΔN_2 (% x 100)
MALES: 7-10*						
Lancaster (N=104)	$288^{\pm 104}$	$342^{\pm 134}$	$293^{\pm 174}$	$153^{\pm 130}$	$299^{\pm 179}$	$-6.2^{\pm 10.6}$
Long Beach (N=34)	$289^{\pm 89}$	$331^{\pm 96}$	$309^{\pm 154}$	$183^{\pm 115}$	$324^{\pm 158}$	$-0.3^{\pm 8.0}$
Glendora (N=92)	$276^{\pm 117}$	$324^{\pm 129}$	$261^{\pm 177}$	$133^{\pm 116}$	$280^{\pm 194}$	$4.8^{\pm 12.4}$
11-14						
Lancaster (N=101)	$304^{\pm 99}$	$349^{\pm 120}$	$333^{\pm 172}$	$173^{\pm 156}$	$317^{\pm 198}$	$-2.2^{\pm 8.0}$
Long Beach (N=17)	$299^{\pm 96}$	$340^{\pm 120}$	$313^{\pm 117}$	$167^{\pm 90}$	$315^{\pm 156}$	$0.2^{\pm 7.5}$
Glendora (N=80)	$316^{\pm 114}$	$367^{\pm 136}$	$304^{\pm 152}$	$180^{\pm 120}$	$331^{\pm 180}$	$4.5^{\pm 15.6}$
15-18						
Lancaster (N=36)	$53^{\pm 90}$	$62^{\pm 91}$	$41^{\pm 160}$	$-18^{\pm 176}$	$24^{\pm 216}$	$-3.0^{\pm 10.1}$
Long Beach (N=16)	$37^{\pm 56}$	$39^{\pm 71}$	$0^{\pm 88}$	$-20^{\pm 54}$	$-10^{\pm 103}$	$3.2^{\pm 8.3}$
Glendora (N=45)	$81^{\pm 112}$	$75^{\pm 124}$	$72^{\pm 183}$	$11^{\pm 147}$	$78^{\pm 214}$	$9.4^{\pm 10.2}$
19-24						
Lancaster (N=23)	$-18^{\pm 58}$	$-12^{\pm 65}$	$-13^{\pm 91}$	$-48^{\pm 97}$	$-6^{\pm 143}$	$1.3^{\pm 9.0}$
Long Beach (N=24)	$-74^{\pm 65}$	$-73^{\pm 70}$	$-130^{\pm 109}$	$-103^{\pm 93}$	$-144^{\pm 166}$	$0.4^{\pm 4.2}$
Glendora (N=32)	$-39^{\pm 57}$	$-42^{\pm 81}$	$-70^{\pm 101}$	$-91^{\pm 104}$	$-54^{\pm 162}$	$6.7^{\pm 12.5}$

(Table 18 continues on next page.)

(Table 18 - continuation)

FEMALES: 7-10						
Lancaster (N=75)	$235^{\pm58}$	$259^{\pm74}$	$271^{\pm134}$	$130^{\pm104}$	$260^{\pm155}$	$-7.2^{\pm11.4}$
Long Beach (N=34)	$207^{\pm53}$	$215^{\pm79}$	$251^{\pm136}$	$150^{\pm108}$	$229^{\pm128}$	$3.4^{\pm8.0}$
Glendora (N=91)	$222^{\pm75}$	$242^{\pm90}$	$256^{\pm131}$	$151^{\pm112}$	$259^{\pm145}$	$2.8^{\pm17.4}$
11-14						
Lancaster (N=105)	$122^{\pm89}$	$121^{\pm100}$	$141^{\pm154}$	$90^{\pm130}$	$108^{\pm174}$	$-1.1^{\pm10.8}$
Long Beach (N=26)	$65^{\pm76}$	$73^{\pm103}$	$53^{\pm116}$	$3^{\pm112}$	$33^{\pm108}$	$5.6^{\pm9.6}$
Glendora (N=85)	$123^{\pm94}$	$131^{\pm110}$	$126^{\pm162}$	$76^{\pm135}$	$112^{\pm163}$	$7.7^{\pm15.2}$
15-18						
Lancaster (N=56)	$6^{\pm49}$	$21^{\pm63}$	$-34^{\pm108}$	$-49^{\pm124}$	$-37^{\pm135}$	$-0.6^{\pm11.4}$
Long Beach (N=19)	$-12^{\pm43}$	$-12^{\pm42}$	$-72^{\pm78}$	$-57^{\pm65}$	$-77^{\pm76}$	$5.0^{\pm7.7}$
Glendora (N=48)	$-5^{\pm44}$	$-11^{\pm56}$	$-22^{\pm105}$	$-41^{\pm93}$	$-26^{\pm116}$	$8.1^{\pm11.1}$
19-24						
Lancaster (N=30)	$0^{\pm57}$	$-1^{\pm76}$	$-25^{\pm100}$	$-51^{\pm86}$	$-17^{\pm126}$	$-3.0^{\pm9.6}$
Long Beach (N=37)	$-18^{\pm78}$	$-17^{\pm100}$	$-62^{\pm88}$	$-67^{\pm81}$	$-77^{\pm94}$	$2.7^{\pm7.3}$
Glendora (N=46)	$-23^{\pm47}$	$-26^{\pm61}$	$-70^{\pm112}$	$-54^{\pm92}$	$-102^{\pm120}$	$7.6^{\pm11.9}$

+ White only

* Age at baseline

** Mean of annualized five-year decrease ± standard deviation
Mean = T_1 - T_2/elapsed months x 12

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Table 19. Average Annual Decrease in Lung Function Bet seline and Retest Five Years Later in Participants* 25-59 Years Old in Lancaster, Long Beach a ndora

GROUP	FEV_1 (ml)	FVC (ml)	FEF_{25-75} (ml/sec)	$\dot{V}_{50}$ (ml/sec)	$\dot{V}_{75}$ (ml/sec)	ΔN_2 (% x 100)
MALES: Never Smokers						
Lancaster (N=142)	$50^{\pm61}$**	$56^{\pm79}$	$51^{\pm132}$	$73^{\pm238}$	$44^{\pm106}$	$2.2^{\pm12.6}$
Long Beach (N=124)	$65^{\pm48}$	$82^{\pm70}$	$93^{\pm105}$	$123^{\pm146}$	$55^{\pm84}$	$(+)3.3^{\pm9.7}$
Glendora (N=147)	$56^{\pm50}$	$71^{\pm74}$	$95^{\pm131}$	$125^{\pm191}$	$65^{\pm106}$	$(+)4.4^{\pm12.2}$
Smokers						
Lancaster (N=169)	$54^{\pm58}$	$55^{\pm81}$	$81^{\pm128}$	$119^{\pm202}$	$58^{\pm90}$	$(+)0.8^{\pm13.9}$
Long Beach (N=101)	$78^{\pm71}$	$97^{\pm108}$	$122^{\pm112}$	$162^{\pm127}$	$73^{\pm86}$	$(+)7.4^{\pm14.8}$
Glendora (N=133)	$70^{\pm60}$	$83^{\pm79}$	$113^{\pm137}$	$143^{\pm178}$	$66^{\pm80}$	$(+)11.0^{\pm15.5}$
FEMALES: Never Smokers						
Lancaster (N=263)	$36^{\pm42}$	$41^{\pm61}$	$56^{\pm112}$	$86^{\pm140}$	$41^{\pm116}$	$1.3^{\pm12.0}$
Long Beach (N=192)	$50^{\pm42}$	$60^{\pm58}$	$79^{\pm94}$	$112^{\pm100}$	$41^{\pm68}$	$(+)5.8^{\pm12.3}$
Glendora (N=291)	$47^{\pm40}$	$47^{\pm58}$	$100^{\pm109}$	$109^{\pm128}$	$76^{\pm85}$	$(+)6.1^{\pm15.4}$
Smokers						
Lancaster (N=151)	$48^{\pm44}$	$57^{\pm64}$	$57^{\pm103}$	$85^{\pm146}$	$43^{\pm101}$	$(+)2.4^{\pm19.0}$
Long Beach (N=114)	$54^{\pm47}$	$57^{\pm54}$	$99^{\pm107}$	$124^{\pm122}$	$65^{\pm71}$	$(+)14.6^{\pm17.4}$
Glendora (N=131)	$45^{\pm43}$	$51^{\pm63}$	$82^{\pm108}$	$102^{\pm120}$	$57^{\pm95}$	$(+)11.7^{\pm24.3}$

* White only, did not change job or residence because of a lung problem; FEV1 exists at both times.

** Mean of annualized five-year decrease ± standard deviation
Mean = T_1 - T_2/elapsed months x 12

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Table 20. Changes in Smoking Status

Percent of Smokers* at Baseline Who Quit Smoking by Retest			
Sex	Lancaster % (N_Q/N_T)+	Long Beach % (N_Q/N_T)	Glendora % (N_Q/N_T)
Males	25.9 (44 /170)	34.0 (34/100)	23.3 (31 /133)
Females	12.7 (19 /150)	19.3 (22 /114)	23.7 (31/131)

Percent of Never Smokers* at Baseline Who Began Smoking by Time 2			
Sex	Lancaster % (N_B/N_T)	Long Beach % (N_B/N_T)	Glendora % (N_B/N_T)
Males	6.3 (9/143)	3.3 (4/122)	4.1 (6/147)
Females	1.5 (4/263)	2.0 (4/197)	2.1 (6/291)

* White only; 25-59 years of age at baseline; did not change job or residence because of a lung problem; FEV_1 exists at both times.

\+ Number who quit ÷ number retested

Table 21. Significance Levels for Differences Among Never Smokers in Rate of Change Between Lancaster and Two Communities Chronically Exposed to Air Pollutants

AREA/TEST	AGE GROUP				
	7-10 Years	11-14 Years	15-18 Years	19-24 Years	25-59 Years
			FEMALES		
Glendora					
FEV_1					.01
FVC			.01		
FEF_{25-75}					.01
$\dot{V}_{50}$				.01	.05
$\dot{V}_{75}$					.01
ΔN_2	.01	.01	.01	.01	.01
Long Beach					
FEV_1	.05	.01			.01
FVC	.01	.05	.01		.01
FEF_{25-75}		.01			.05
$\dot{V}_{50}$		.05		.05	.05
$\dot{V}_{75}$		.01			
ΔN_2	.01	.01		.05	.01
			MALES		
Glendora					
FEV_1					
FVC					
FEF_{25-75}				.05	.01
$\dot{V}_{50}$					.05
$\dot{V}_{75}$					
ΔN_2	.01	.01	.01		.01
Long Beach					
FEV_1				.01	.05
FVC				.01	.01
FEF_{25-75}				.01	.01
$\dot{V}_{50}$				.01	.05
$\dot{V}_{75}$					
ΔN_2	.01		.05		.01

Table 22. Levels of Significance for Differences in Rate of Change Between Current Smokers in Lancaster and Two Study Areas Chronically Exposed to Air Pollutants

	25 - 59 YEARS	
	Glendora	Long Beach
Males		
FEV_1	.05	.01
FVC	.01	.01
FEF_{25-75}	.05	.01
$\dot{V}_{50}$		
$\dot{V}_{75}$		
ΔN_2	.01	.01
Females		
FEV_1		
FVC		
FEF_{25-75}		.01
$\dot{V}_{50}$		.05
$\dot{V}_{75}$		
ΔN_2	.01	.01

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Bibliography and List of Appendices

(Items 1-15 of the bibliography are Appendices 1-15 to the report. These Appendices are available upon request to the Air Resources Board. Note, however, that Appendices 1-12 and 14 are published or submitted papers.)

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