LUNG FUNCTION STATUS OF SOME ETHIOPIANS EXPOSED TO OCCUPATIONAL DUSTS

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D E D I C A T I O N

To my grand father, Shaleka Basha Bekele Sahlemariam.

A C K N O W L E D G E M E N T S

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TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

A B S T R A C T

Acute and chronic changes of ventilatory capacities and the prevalences of respiratory symptoms were studied in 233 (117 males and 116 females) nonsmoking factory workers exposed to cotton, tobacco and cement dusts. Two hundred and thirty six (125 males and 111 females) workers who were nonsmokers and had no exposure to occupational dusts were taken as non-exposed subjects. An attempt was made to see values of ventilatory indices in relation to dust concentration and duration of exposure. Comparison was also made between dust concentrations recorded in this study and standards recommended by ACGIH and WHO.

Prevalences of respiratory symptoms (chronic cough, chronic bronchitis, and bronchial asthma) were found to be higher in all dust-exposed groups than they were in the non-exposed subjects. All respiratory symptoms considered in the present study were found in cement and cotton workers much more frequently than in the non-exposed subjects. Only chronic cough was found to be more frequent among tobacco workers than among the non-exposed subjects.

Significant reductions of FVC, FEV_1, MMFR and PEFR values over the workshift were recorded among cotton and tobacco workers. Acute reductions in cement workers were recorded only in FVC and PEFR. Significantly reduced mean values of FEV_1%, FEF, MMFR in both sexes of exposed subjects and FEV_1 and PEFR in male exposed

subjects were recorded. After matching of exposed subjects, from each factory, with the non-exposed subjects according to their age and height, significantly reduced mean values of $FEV_1\%$, FEF, MMFR in both sexes of cotton workers and PEFR in male cotton workers were recorded. Mean values of $FEV_1\%$ and MMFR in cement workers, FEV_1 in female tobacco workers and PEFR, MV and MVV in male tobacco workers were found to be significantly lower than in the non-exposed subjects. Substantial number of workers were found to have lower values of ventilatory capacities than their predicted values by more than two standard errors of estimate. Predicted values of ventilatory indices were calculated for both sexes by means of multiple linear regression equations, developed on the basis of data obtained in the non-exposed subjects.

Mean percentages of predicted lung function values in workers exposed to relatively high dust concentration were found to be lower than the values observed in those exposed to lower concentration, but significant differences (in $FEV_1\%$) were observed only in cement workers.

Strong negative correlations ($r \leq -0.30$) were recorded between duration of exposure and FVC, FEV_1, $FEV_1\%$ and MMFR values in male exposed subjects. Negative correlations were also observed among females, but the relationships were not as strong as that of males. When compared with standards of ACGIH and WHO, the dust concentrations in cement and yarn factories were found to be high.

I N T R O D U C T I O N

During the time of Industrial Revolution people were not aware of the presence of industrial hazards to which most workers were victims. As progresses were made in technology from time to time, there was a gradual recognition of hazards encountered in work places and hence preventive measures were started to be implemented, particularly in developed countries, to meet the health needs of working men and women. But in many developing countries, including Ethiopia, there is still unawareness and some lack of concern about occupational hazards and as a result, there is no standard assessment of working conditions. This leads to the high prevalence of environmental factors that cause the impairment of the health of workers in factories.

Environmental factors in factories which may cause impaired health or significant discomfort may be classified as physical, chemical, biological and ergonomic hazards (National Safety Council (NSC), 1979). The present study focuses on hazards of chemicals found in working places, in the form of dust particles.

Industrial dusts can be classified into two broad categories - organic (dusts of vegetables and animals in origin) and inorganic dusts. Inorganic dusts are further classified as metallic and non-metallic ones depending upon whether or not they contain silica. Again the latter may be classified as crystalline or amorphous (NSC, 1979).

Dust particles are known to cause diseases of the skin (Edward, 1984; WHO, 1984), eyes (Vedal *et al.*, 1986), gastrointestinal tract (Prodan, 1983; Neuberger, 1984; WHO, 1984) and respiratory system of workers exposed to them. Furthermore, soluble dusts cause damage to the internal organs of the body reaching them, from external organs, through blood vessels (Haubulein *et al.*, 1983).

The problems associated with various kinds of respiratory diseases emanating from industrial dusts are influenced by four critical factors: **1)** the type of dust involved (organic or inorganic), **2)** the duration of exposure (possibly in years), **3)** the concentration of airborne dusts in the breathing zone of the exposed, and **4)** the size of dust particles, present in the breathing zone (ILO, 1965 ; NSC, 1979 ; WHO, 1984).

Various methods are used to assess the effect of exposure to industrial dusts on the respiratory system. These include history and physical examinations (Gaensler & Wright, 1966; Morgan, 1978), roentgenographic examinations (Keith & Morgan, 1979; Viallat *et al.*, 1983; Oleru, 1984), transfer factor measurements (Cotes, 1979; Keith & Morgan, 1979; Lloyd *et al.*, 1984) and pulmonary function tests (Cotes, 1979).

The study of the lung function status of workers exposed to occupational dusts is essential in detecting respiratory changes and in revealing the presence or absence of minor degrees of lung tissue damage. Information on occupational lung diseases combined with environmental measurements provides a basis for the establishment of safe working conditions (Cotes, 1983).

Many investigators have reported the effects of occupational dusts on respiratory system employing various pulmonary function tests. Even though occupational lung diseases have been recognized since the 16^{th} century (Robert, 1984) and studied very well in industrialized countries for many years now, similar studies (employing lung function tests) have not been made on the Ethiopian situation. So far, there is no report on the effect of occupational dusts on the respiratory system of Ethiopians except one limited study, which was carried out by Mintesinot (1988), dealing only with an acute and chronic effects of cotton dust on FVC and FEV_1 of Ethiopians working at Bahir Dar Textile Mill. To have sufficient documents on occupational lung diseases in Ethiopians, the present study was conducted in persons working in different working conditions.

In the present study, respiratory impairments were evaluated in the light of findings on medical histories and the measurements of various mechanical lung function parameters of workers exposed to dust, in relation to dust concentration and duration of exposure, in Adey Abeba yarn, Addis Ababa Cigarette and Addis Ababa Cement factories. Thus the primary purposes of this study are:

1) to assess the acute and chronic lung function effects of occupational dusts on exposed groups;
2) to determine the correlation of exposure time and

dust concentration with the impairment of respiratory system;

3) to compare the degrees of lung impairment of workers exposed to different kinds of dusts; and

4) to compare dust concentrations in the selected factories with the standards set by other countries and international bodies.

The lung function indices which were dealt within this study are, forced vital capacity (FVC), forced expiratory volume in one-second (FEV_1), the percentage of forced expiratory volume in one-second ($FEV_1\%$), forced expiratory flow ($FEF_{200-1200}$), maximal midexpiratory flow (MMFR or $FEF_{25\%-75\%}$), maximal voluntary ventilation (MVV), peak expiratory flow rate (PEFR) and minute ventilation (MV). These are explained in Appendix I.

L I T E R A T U R E   R E V I E W

The assessment of various pulmonary function indices is generally valuable in determining: **1)** the presence of lung diseases; **2)** the extent of abnormalities; **3)** the progression of the disease and; **4)** the course of therapy in treatment of the particular disease (Ruppel, 1979; Pennock *et al.*, 1983). Furthermore, they are important in the evaluation of pulmonary disability for the purpose of insurance and workmen's compensation (West, 1979; Pennock *et al.*, 1983). They are also employed in epidemiological surveys to assess industrial hazards or to document the incidence of lung diseases in the community (West, 1979).

Lung function depends on sex and anthropometric measurements.

The influence of sex on pulmonary function indices is a well recognized fact. In general terms, the female lung is usually smaller and hence her overall ventilatory performance is inferior to that of the male (Cotes, 1983).

Apart from sex, there are several reports which reveal that some anthropometric measurements also have significant relationships with various ventilatory indices. In particular height and age are the most established measurements in showing consistent and significant correlations with most indices of lung function. Concerning this, Kory and his collaboraters (1961) reported the respective direct and inverse relations of height and age with VC, FEV_1 and MVV by conducting a study on 468 normal men. The same result was reported on FVC, FEV_1 and

$FEV_{0.75}$ by Da Costa (1971), Malik *et al.* (1972), Cole (1974) and Heller *et al.* (1986). The inverse relation of FEV_1% with age had been demonstrated by several authors (Berglund *et al.*, 1963; Malik *et al.*, 1972; Miller *et al.*, 1972; Heller *et al.*, 1986). In addition to these, PEFR is also reported to have negative correlation with age in adults of both sexes (Higgins, 1957; Flint & Kahan, 1962; Pelzer & Thomson, 1964; Kamat *et al.*, 1967; Mengesha & Mekonnen, 1985).

Besides age and height, weight, fat free mass, chest circumference and body surface area have also been reported to show linear relationships with some lung function indices. The degree of their correlation, however, is not as significant as that of age and height (Kory *et al.*, 1961; Miller *et al.*, 1970).

Lung function depends on ethnic group.

The values of lung function parameters are not only dependent on some anthropometric measurements but also on ethnic group differences - i.e., the lung volumes and capacities widely differ from one ethnic group (standardized for age and height) to another. Abramowitz and associates (1965) studied the vital capacity in males and females of Negro and White people. They found that vital capacities were lower in Negro males than they were in White males. Kamat and co-workers (1967) reported the lower vital capacity (20 to 35 per cent in males and 28 to 32 per cent in females) in Indians than in a comparable western population. Lower values of FVC and FEV_1 were found in normal Ethiopian men and women than in

Whites. Higher values of these same ventilatory indices were recorded in Ethiopians than in other Africans, Chinese, and Indians (Mengesha & Mekonnen, 1985). There are also many other investigators who reported the influence of ethnic group difference on the variability of pulmonary function indices (Miller, *et al.*, 1970; Da Costa, 1971; Femi-Pearse & Elebute, 1971; Miller *et al.*, 1972; Oscherwitz *et al.*, 1972; Mustafa, 1977).

Since the racial difference is one of the factors influencing the values of lung volumes and capacities, the formulation of regression equation (to serve in the prediction of normal values) for each ethnic group have been suggested by some authorities (WHO, 1983).

Lung function values as affected by smoking of cigarettes.

The effect of cigarette smoking on the function of the lung was not considered until recent times. Previously, investigators used to conduct lung function tests, in the establishment of the prediction formula for a certain group of people, without particular regard to the smoking habit. But researchers in the seventies had developed prediction equations with consideration of smoking. For instance Morris *et al.* (1971) and Cherniack and Raber (1972) had developed regression equations for FVC, FEV_1, $FEV_1\%$ and FEF by carrying out tests on only nonsmokers. This resulted in a better regression on age and height than was previously reported by others. Recently, Heller and collaborates (1986) reported the presence of significantly lower FEV_1, $FEV_1\%$ and $FEF_{25\%-75\%}$ values in heavy

Weill & Jones, 1975). Out of 126 grindstone cutters in the north of Nigeria, Warrell and associates (1975) found 10 workers with FEV_1/FVC ratio less than their predicted values by more than 2 standard deviations. Similarly, Jain and Patrick (1981) reported the significantly reduced FEV_1/FVC ratio in Nigerian coal mine faceworkers. Furthermore, a significantly lower value of this ratio was found among cement workers in Yugoslavia than among the non-exposed groups with fairly similar height, age and weight distribution (Kalacic, 1973).

Significantly lower values of FVC and FEV_1 in Nigerian nonsoapy detergent factory workers were recently reported by Oleru (1984).

Values of MMFR lower in silicotic South African gold miners than in nonsilicotic ones had also been demonstrated by Irwig and Rocks (1978).

The reduced FEV_1 values of cotton workers over the work shift (which shows the acute effect) had been demonstrated by many investigators (Bouhuys *et al.*, 1969; Khogali 1969; Valic & Zuskin 1972(a); Valic & Zuskin 1972(b); Rylander *et al.*, 1979). The acute effect of cotton dust on FVC and PEFR was also reported by Zuskin & Valic (1972) and Valic & Zuskin (1977).

On the other hand, comparison of the pre shift lung function data in hemp, flax, and cotton workers with expected normal values was done by Zuskin and Valic (1976) to see the long term (chronic) effect of the dust. They found that there was a considerably higher loss of FEV_1 values. Similar result was demonstrated by these same workers (1972) and by Kondakis and Pournaras (1965). A greater decline in FEV_1 per year among cotton and hemp workers with a long history of exposure than among control subjects was demonstrated by Berry and co-workers (1973) and Bouhuys & Zuskin (1976) by carrying out a follow-up study, at regular intervals, over a period of 3 and 7 years respectively.

Both acute and chronic effects of cotton dust among Bahir Dar Textile Mill workers in Ethiopia has recently been reported by Mintesinot (1988). After conducting a study on 595 workers exposed to cotton dust (323 males and 272 females), he reported that there were significant changes in FEV_1 values over the work shift in a considerable number of them and there were reduced levels of this same lung function index, in many of them, when compared with their predicted values using a prediction formula developed by Mustafa (1977) worked on Tanzanian and Sudanese subjects.

In addition, other vegetable dusts such as tobacco, sisal, and wood dusts have been reported to cause abnormal function of the respiratory system. Connected with this, Valic and his co-workers (1976) reported the loss of FEV_1 over the work shift after they had carried out a study on 318 female tobacco workers comparing their lung function data with 210 non-exposed female workers. Even though some studies (Gilson *et al.*, 1962) failed to show that sisal dust causes respiratory problems, Mustafa and associates (1978) found that workers in the preparation of sisal fibre showed acute and chronic changes in the FVC and FEV_1 values. Levels of FVC, FEV_1, FEV_1/FVC% and MMFR in saw mill workers exposed to the dust of red cedar (*Thuja Plicata*) were recently observed to be lower than those of control groups - not exposed to air contaminants at work (Vedal *et al.*, 1986).

The degree of lung function impairment, according to several authors, is largely dependent on the concentration of dust in the breathing zone and the duration of exposure. In this regard, after conducting a study on some non smoking female cotton mill workers, Zuskin and Valic (1972) found that the chronic changes of ventilatory capacity were developed only in subjects with a longer exposure to cotton dust. In addition, Hale and Sheers (1963) could not detect silicosis, among granite masons who had less than 15 years of exposure. But after 15 years, according to these authors, the risk of developing the disease (silicosis) was found to be increased.

Even though it is generally accepted that the increasing duration of exposure directly correlates with the degree of respiratory impairment, the finding of contrasting results is not uncommon. For instance, the report of Zuskin and Valic (1972) shows that the acute reduction in ventilatory capacity is essentially the same in both groups of nonbyssinotic textile mill workers with longer and shorter duration of exposure. Gandevia and Milne (1965) also showed the occurrence of significantly large decreases of lung function in those employed in a textile industry (in Australia) for less than a month which is similar to those with long duration of employment.

With regard to the level of dust, Valic and his co-workers (1968) showed the prevalence of marked reductions in the mean $FEV_{0.75}$ and FVC during the work shift in workers exposed to high concentrations of dust in a spinning department of a factory (in Yugoslavia) processing soft hemp (*Cannabis sativa*). Gilson and his associates (1962) reported the prevalence of a reduced level of ventilatory function in a very dusty ginnery. Analysis of the survey of workers in relation to the dust levels was also carried out by Fox and his co-workers (1973) who demonstrated the occurrence of a greater reduction of ventilatory function in cotton workers exposed to higher dust concentration.

The chronic and acute changes in FVC and FEV_1 in sisal workers observed by Mustafa and associates (1978) was also largely related to lengthy exposure and high dust level.

Nonspecific chronic obstructive pulmonary diseases (COPD) are, nowadays, found to be common problems in every society. Disease entities that could be included in the term COPD are chronic cough, chronic bronchitis, asthma, emphysema and bronchiectasis. These respiratory symptoms may largely be caused by environmental pollution, smoking of cigarettes, infection and heredity. Even though they are commonly found in the general population, it has been proved by many investigators that their prevalence is much more higher among those who are occupationally exposed to airborne substances. In this regard Valic and co-workers (1976) have reported the higher prevalence of chronic respiratory symptoms among tobacco workers (females) than among the non-exposed groups. The higher prevalence of cough and dyspnea among talc workers had been reported by Kleinfeld and associates (1965). The prevalence rates of these characteristic respiratory symptoms were also significantly higher in cement workers (in Yugoslavia) than in the non-exposed groups (Kalacic, 1973).

The prevalence of chronic respiratory symptoms, either due to exposure to airborne substances or due to other factors, is found to affect the pulmonary capacities. This is confirmed by the finding of Zuskin and Valic (1972). Their study on some nonsmoking female workers, exposed to cotton dust, revealed that an acute reduction of ventilatory capacity during work shift was mainly attributable to the prevalence of these symptoms.

M A T E R I A L S   A N D   M E T H O D S

Description of the factories.

As previously mentioned, the study was conducted in three different factories viz., Adey Abeba Yarn, Addis Ababa Cigarette and Addis Ababa Cement factories. All of them are located in Addis Ababa.

Adey Abeba Yarn Factory. Adey Abeba Yarn factory, located in the southern part of Addis Ababa and established in the late 1950's, has at present, a working population of 4,000. It has various production sectors with different products, such as yarn, T-shirts, blankets and various other garments. It has two yarn factories, named No. 1 and No. 2. No. 2, with the latest ventilation system installations, was established about 15 years ago, while No.1 was in existence since the 1950's. The No.1 yarn factory has a relatively poor de-dusting system and has a much more cotton dust concentration. This factory has been taken as a study site. It has at present, about 700 dust-exposed workers, who are working in three shifts for 8 hours a day.

Addis Ababa Cigarette Factory. This is located in the southern part of Addis Ababa and it was established in the early 1940's. Various brands of cigarettes viz., Nyala, Gisilla and Gureza are the main products of this factory. At present the factory has about 240 tobacco-dust-exposed workers. The workers do their jobs in two working shifts. The working condition of one of the production sections - blending and cutting - was very dusty. Efficient exhaust ventilation system was installed in this section only twelve years ago.

Addis Ababa Cement Factory. This factory was established in the late 1950's. It is located in the southern parts of Addis Ababa. At present it has about 180 male workers all of whom are exposed to mineral dusts.

Subjects.

Exposed groups. Out of 1120 male and female dust-exposed workers in all selected factories, 233 of them (117 men and 116 women) ranging in age from 20 to 57 years, took part in the study. They were selected randomly after exclusion of smokers for smoking is reported to affect the respiratory system (Heller *et al.*, 1986). Of the selected groups 29 males and 74 females were from Adey Abeba yarn factory; 31 males and 42 females were from Addis Ababa cigarette factory; and 57 males were from Addis Ababa cement factory. All randomly selected workers were taken on the basis of their willingness to take part in the study.

Non-exposed groups. A total of 236 (125 men and 111 women) nonsmoking workers, ranging in age from 21 to 57 years, who didn't have any history of exposure to factory dust were taken to serve as the non-exposed (control) groups. They consisted of sewing machine operators, guards, office-cleaners, office-girls, time keepers and other various administration workers, who apparently have essentially the same living standards as the exposed groups. They were taken from all selected factories, Faculty of Medicine, Faculty of Science (Addis Ababa University), Black Lion Hospital and Addis Glass & Bottle Factory.

Respiratory symptoms.

All workers, who were selected to participate in the study, completed a questionnaire on respiratory symptoms. The British Medical Research Council questionnaire on respiratory symptoms was partially taken (questions about cigarette smoking were excluded) to categorize subjects. The questionnaire was administered by the principal investigator after being briefed on respiratory symptoms and the administration of the questionnaire. The respiratory symptoms considered were the following:

i) chronic cough, if cough was present on most days of the week for at least 3 consecutive months during the year (Vedal *et al.*, 1986)

ii) chronic bronchitis, if cough and phlegm was present for a minimum of 3 months in the year and for at least 2 successive years (American Thoracic Society, 1962; Zuskin & Valic 1972; Valic & Zuskin, 1977; West 1979).

iii) Bronchial Asthma, if wheeze was reported with colds and occasionally apart from colds in addition to the presence of cough and wheeze on most days or nights associated with shortness of breath (Brooks, 1982).

Anthropometric measurements.

Standing height (without shoes), sitting height and body weight (in light clothing) were measured and recorded to the nearest one centimeter and one kilogram respectively. Improvised height measuring scale for both standing and sitting height measurements and a calibrated weight balance for the measurement of weight were used. Age and duration of exposure (in years) and sex of each subject were also recorded. Fat free mass was calculated from the measurement of skinfold thickness (in mm) using Harpenden skinfold caliper, which exerts 10 gm/mm^2 pressure. The measurement of skinfold thickness was done on the triceps and biceps of each subject's arm, where good folds of skin could be raised (Fig. I). Before determining the value of fat free mass, body density and percentage of body fat are calculated. These were obtained by using the prediction equations (Durnin & Womerslay, 1974) given below:

$$\text{Body density} = c - m \times \log \text{skin fold}$$

where, c = 1.1356 for men
c = 1.1362 for women
m = 0.0700 for men
m = 0.0740 for women

$$\%\text{ of body Fat} = \left(\frac{4.95}{density} - 4.5\right) \times 100 kg$$

$$FFM = \frac{bodywt. \times (100 - Fat\%)}{100} \text{ kg}$$

Pulmonary Function.

Lung function measurements were carried out in each factory and in the physiology laboratory of Medical Faculty using:

1) a dry wedge Vitalograph spirometer (7.8 L) (Vitalograph Ltd. Buckingham) to find FVC, FEV_1, FEV_1%, FEF and MMFR values (Fig.II).

2) Max-plank Respirometer for the measurement of MV (Fig.III);

3) Wright Peak Flow Meter to find PEFR value (Fig.IV); and

4) Douglas bag to measure MVV (Fig.V).

Room temperature and barometric pressure values of the study room were measured to correct gas volumes from ATPS (ambient temperature, pressure, saturated with water vapour) to BTPS (body temperature, pressure, saturated with water vapour). A clinical thermometer and a pocket-Altimeter were used for this purpose. Nose clips and plastic mouthpieces were also used in measuring all lung volumes and capacities.

Lung function testing procedure. The purpose of the test was explained to each subject to obtain his/her consent. Then the procedures for the pulmonary function tests on each instrument were carefully explained and demonstrated.

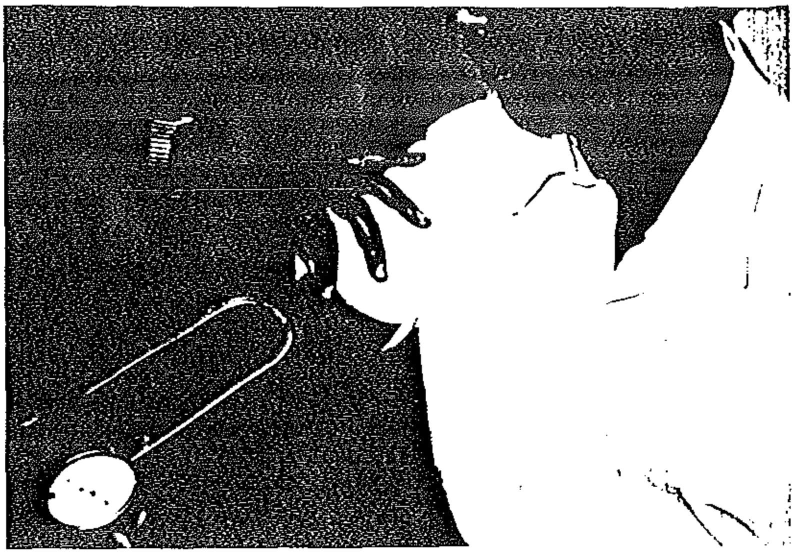


Fig.I. Measurement of skinfold thickness using Harpenden Skinfold Caliper.

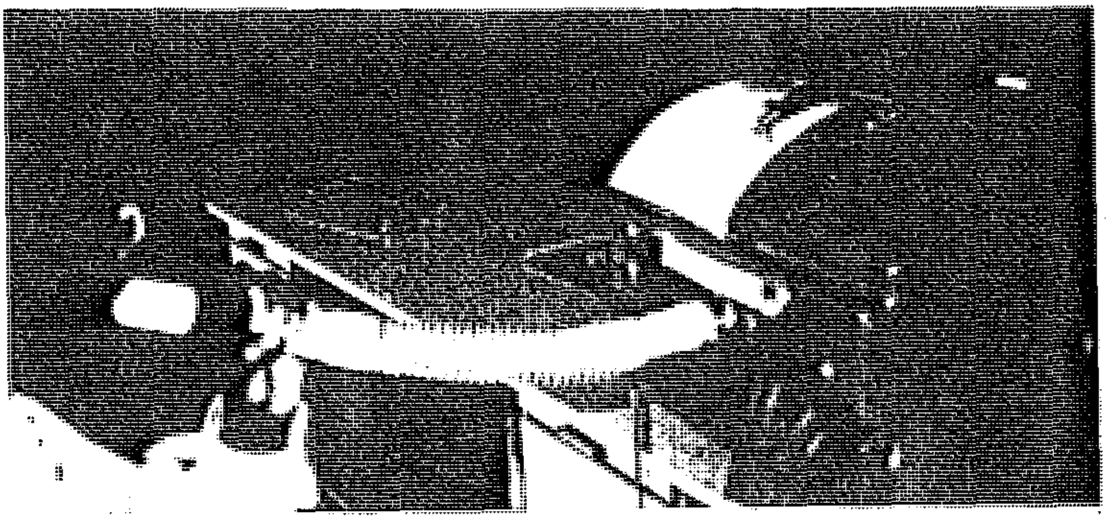


Fig. II. Lung function measurement using Vitalograph Spirometer.

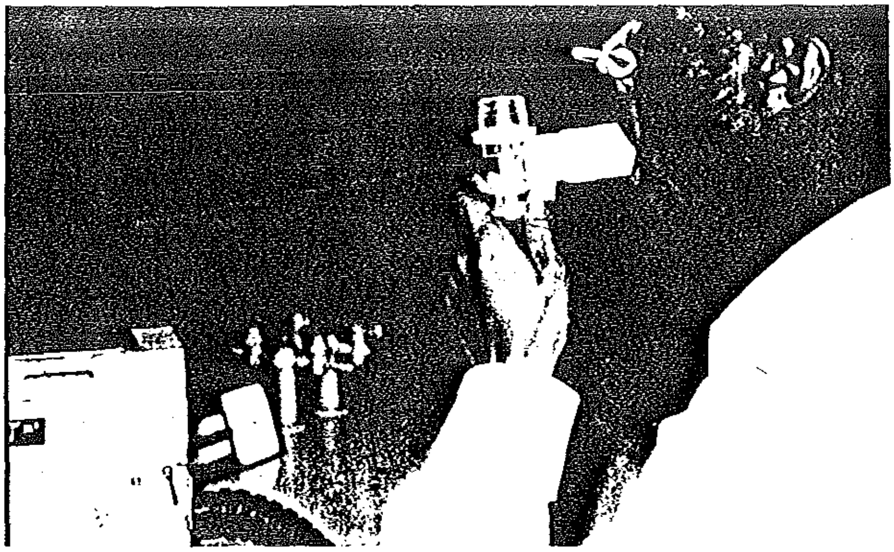


Fig. III. Measurement of MV using Max-plank Respirometer.

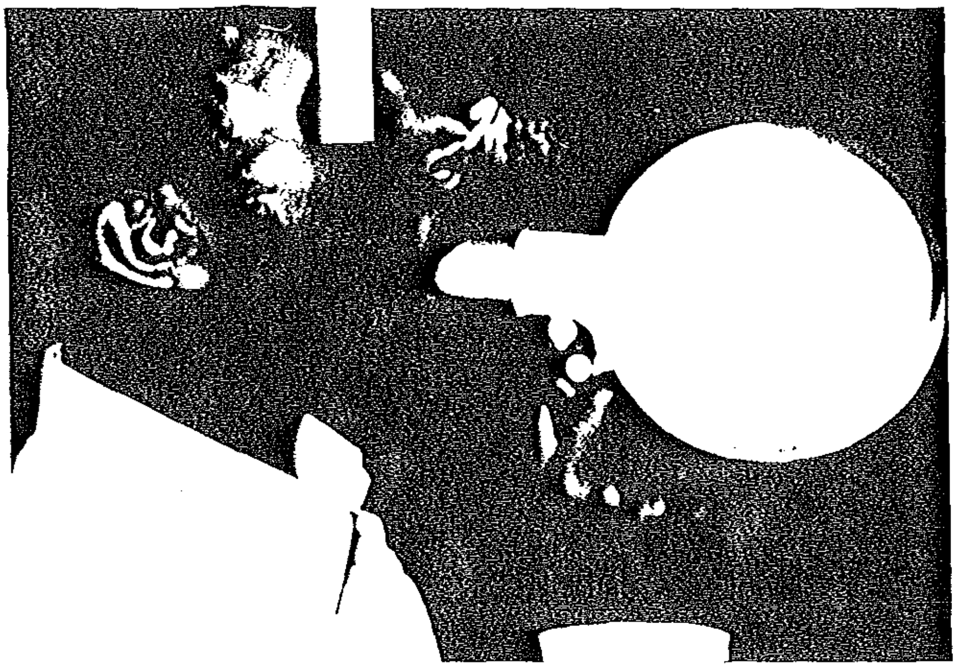


Fig. IV. Measurement of PEFR using Wright Peak Flow Meter.

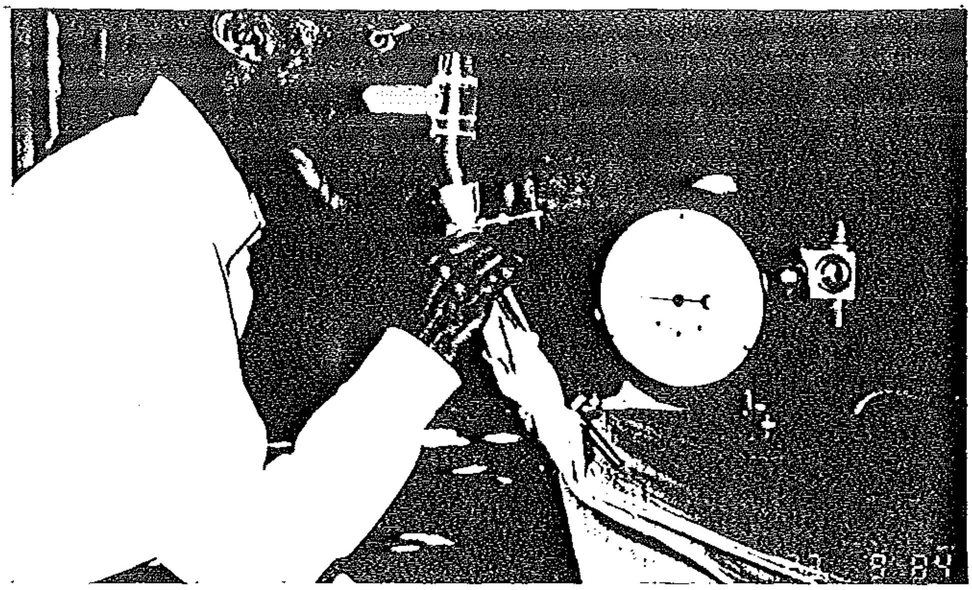


Fig V. Measurement of MVV using Douglas bag.

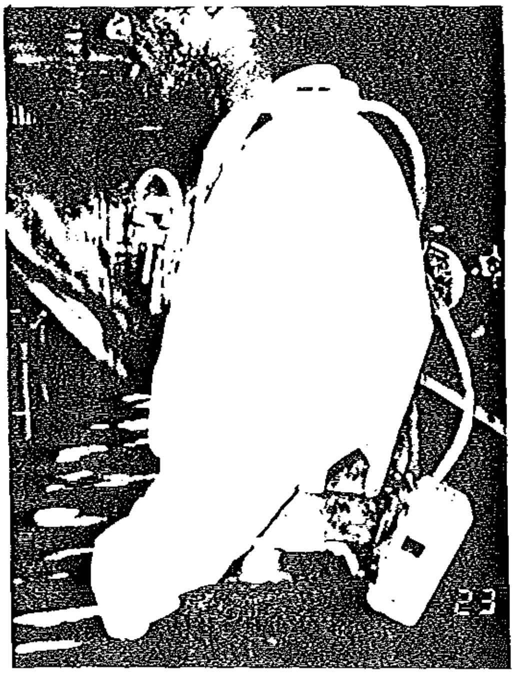


Fig. VI. Respirable dust sampling instrument (Casella London personal dust sampler).

Test using vitalograph spirometer. The subject was instructed to practice making deep inspiration and complete forceful expiration before he/she was connected to the apparatus. Trial manoeuvres on the vitalograph were made prior to each test. Then three readings were taken after ensuring that he/she had performed as required during the trial manoeuvres. A rest of about two minutes was given to the subject between each measurement.

The tests were performed before (on all subjects) and immediately after (on some volunteer exposed subjects) the end of the work shift. The latter tests were conducted using only the vitalograph and Wright peak flow meter.

An expiratory spirogram which showed the highest value of FVC and FEV_1 was taken so as to analyse the actual results of lung function indices, i.e., FVC, FEV_1, $FEV_1\%$, FEF and MMFR (Da Costa, 1971; Merchant *et al.*, 1974; Irwig & Rocks, 1978; Vedal *et al.*, 1986).

Test using Wright peak flow meter. The manoeuvre was similar to that of the vitalograph. The highest PEFR record was taken as the actual value after three efforts were made by each subject.

Test using Max-plank respirometer. The subject was first allowed to breath normally for a minute or two (being attached to the respirometer) so that he/she might be acquainted with the manoeuvre and the apparatus. Then measurement of minute ventilation followed for three minutes.

Test using Douglas bag. Deep and rapid inspiration and expiration were first demonstrated to the subject before he/she was connected to the bag and was allowed to make the same manoeuvre for 10 seconds (Ruppel, 1979). The gas collected in the bag over a given period of time was measured by a gas meter.

Spirometric and PEFR measurements were made with the subject standing and MV and MVV measurements were conducted in a sitting position.

Gas volumes obtained were corrected to BTPS using the formula (Cotes, 1979) shown below:

$$V_{BTPS} = V_{ATPS} \times \frac{273+37}{273+t} \times \frac{P_B - P_{H_2O}(t)}{P_B - P_{H_2O}(37)}$$

Where, V is the gas volume under the conditions specified, t is the ambient temperature and 37 is body temperature in °C, P_B is barometric pressure, $P_{H_2O}(t)$ is vapour pressure of water at the ambient temperature and $P_{H_2O}(37)$ is vapour pressure at body temperature which is 47 according to Ruppel (1979).

Measurement of environmental dusts.

Measurements of respirable airborne dust concentration were made using a personal dust sampler (Casella London Ltd.) as recommended by WHO (1984). The sampler is made to be worn by the worker (Fig.VI on page 21). It consists of a filter cassette (37 mm in diameter) in a filter holder through which air can be moved by a battery-powered motor. The filter holder is connected by a length of flexible plastic tube to the pulsation damper and from the damper to the inlet of the motor (sampler). During sampling, the air mover was hooked to the belt and the filter holder was affixed to the collar - a suitable site in the breathing zone of the worker.

The flow rate calibration was made by a rotameter (part of the apparatus). Watman GF/A glass fibre filter (37 mm in diameter) was preferred, for dust collection, to other types because of its low hygroscopic nature and its low resistance to airflow (ACGIH, 1983).

Sampling was undertaken in the range of 4 to 6 hours in different dusty sections. A total of 29, 12 and 11 samples were obtained from Adey Abeba Yarn, Addis Ababa Cigarette and Addis Ababa Cement factories respectively.

Dust concentration expressed in mg/m^3 was calculated from the change in weight of the filter, before and after sampling, divided by the volume of air sampled. The formula used is shown below:

$$\text{Concentration in mg/m}^3 = \frac{\mathit{finalwt.-Initialwt.}}{\mathit{Time}(\text{min.})\times \mathit{Flowrate}(L/\text{min.})}\times 1000$$

Metler analytical balance at a sensitivity level of 10^{-5} (0.00001)gm was used in the measurement of filters' weight before and after sampling.

Statistical analysis.

Differences in the proportion of respiratory symptoms and in the mean values of various pulmonary function measurements between non-exposed and exposed groups, between subjects in one factory and the other and between pre shift and post shift lung function values were examined by Student's-t test and z test.

Among the study subjects, those who showed lung function indices lower than their predicted values by more than two standard errors of estimate were considered to be affected substantially (Kory *et al.*, 1961; Warell *et al.*, 1975). Predicted values were obtained using the prediction formulas developed from the lung function data of the non-exposed subjects. Prediction equations for each best correlated ventilatory index with either one or more anthropometric measurements were developed using IBM PS/2 (mode 50) computer. In addition to these all descriptive statistics viz., mean, standard deviation, minimum and maximum values for all pulmonary function variables were computed. In the significance tests, critical p-values of 0.05, 0.025, 0.01 and 0.001 were used.

R E S U L T S

Respiratory symptoms.

The prevalences of respiratory symptoms (chronic cough, chronic bronchitis and bronchial asthma) among male and female subjects of the exposed (in all factories) and the non-exposed groups are separately shown in Tables I(a) and I(b). As seen in these tables, there were no substantial differences between sexes of both non-exposed and exposed subjects in the rates of prevalences of respiratory symptoms. Since differences in the rate of prevalences between sexes is highly minimal, the need to separate subjects according to their sex is not as such important when comparing prevalences of respiratory symptoms between the non-exposed and exposed subjects and comparing prevalences in exposed subjects of one factory with subjects of the other.

The prevalence rates of respiratory symptoms among 236 non-exposed and 233 exposed subjects are presented in Table II. It can be seen, in this table, that the prevalence rates of all symptoms in dust-exposed groups were significantly ($P<0.001$) different from the non-exposed groups. In particular cases (Table III) it can be seen that all symptoms were consistently more frequent in cement and cotton workers ($P<0.001$) than they were in the non-exposed groups while significantly high ($P<0.05$) prevalence of only chronic cough is seen in tobacco workers when compared with that of the non-exposed groups.

Table I(a). The prevalences of respiratory symptoms in male and female non-exposed subjects.

Respiratory symptom	Male, n=125 (%)	Female, n=111 (%)	Signi-ficance
Chronic Cough	9(7.20)	10(9.01)	NS*
Chronic Bronchitis	11(8.80)	9(8.11)	NS
Bronchial Asthma	12(9.60)	6(5.41)	NS

* Not significant

Table I(b). The prevalences of respiratory symptoms in male and female exposed subjects.

Respiratory Symptoms	Male, n=117 (%)	Female, n=116 (%)	Signi-ficance
Chronic Cough	29(24.79)	23(19.83)	NS
Chronic Bronchitis	25(21.37)	21(18.10)	NS
Bronchial Asthma	30(25.64)	21(18.10)	NS

Table II. The prevalences of respiratory symptoms in all non-exposed and exposed subjects.

Respiratory symptoms	non-exposed n=236 (%)	Exposed n=233 (%)	Signi-ficance
Chronic cough	19(8.05)	52(22.32)	P<0.001
Chronic Bronchitis	20(8.48)	46(19.74)	P<0.001
Bronchial Asthma	18(7.63)	51(21.89)	p<0.001

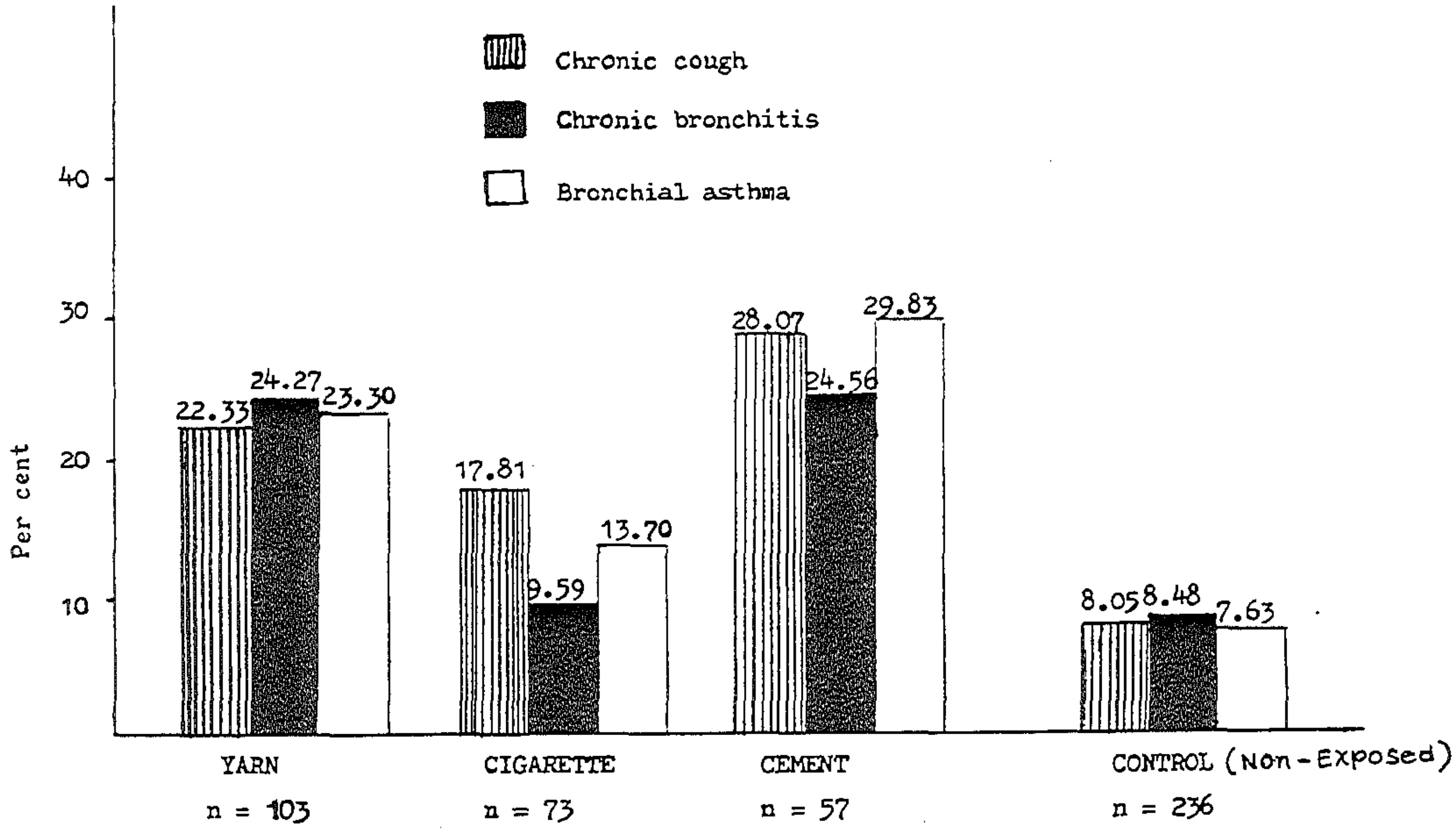
Table III. The prevalence of respiratory symptoms in the non-exposed subjects and exposed subjects of each factory.

Respiratory symptoms	1 Cement n=57	2 Cigarette n=73	3 Yarn n=103	4 non-exposed n=236
* Chronic Cough	16(28.07%)	13(17.81%)	23(22.33%)	19(8.05)
** Chronic Bronchitis	14(24.56%)	7(9.59%)	25(24.27%)	20(8.48)
***Bronchial Asthma	17(29.83%)	10(13.70%)	24(23.30%)	18(7.63)

S I G N I F I C A N C E					
1 vs 4	2 vs 4	3 vs 4	1 vs 2	1 vs 3	2 vs 3
* P<0.001	P<0.05	P<0.001	NS	NS	NS
** P<0.001	NS	P<0.001	P<0.05	NS	P<0.05
*** P<0.001	NS	P<0.001	P<0.05	NS	NS

It is also observed that the prevalences of both chronic bronchitis and bronchial asthma were more frequent among cement workers than among tobacco workers (P<0.05). The prevalence of chronic bronchitis in cotton workers was found to be higher (P<0.05) than in tobacco workers. There was no difference in the prevalence rates of symptoms between cement and cotton workers. The summary of prevalence of respiratory symptoms among workers of each factory and among the non-exposed groups is presented in fig.VII.

Fig. VII: The prevalence of chronic respiratory symptoms in subjects of each factory compared with the non-exposed groups



Pulmonary functions.

Even though a total of 233 and 236 exposed and non-exposed subjects (respectively) of both sexes took part in the present study, all of them were not accepted in the tests of lung function due mainly, to the fact that some were quite unable to perform the manoeuvre of spirometry. Due to this reason 22 exposed (7 males and 15 females) and 25 non-exposed (15 males and 10 females) subjects were excluded from the study of lung function and results of lung function tests for 211 exposed (110 males and 101 females) and 211 non-exposed (110 males and 101 females) subjects were taken to be analysed.

The anthropometric measurements of the exposed groups were fairly similar to that of their corresponding non-exposed groups. The mean, standard deviation and the range of anthropometric measurements for both non-exposed and exposed (males and females) subjects are presented separately in Tables IV (a) through IV(d). As mentioned earlier, the socioeconomic status of the two groups was fairly similar. Estimation of living standard for each subject was made on the basis of his/her monthly income and family size. In other words, non-exposed subjects with apparently similar monthly income and family size to that of the exposed subjects were chosen to take part in the study.

Table IV. Mean, standard deviation and range of anthropometric characteristics in both exposed and non-exposed subjects.

IV(a) Non-exposed (males)

	Mean ± S.D	Range
Age (Yr.)	38.94 ± 9.32	21.00 - 57.00
Standing height(cm)	168.85 ± 5.78	156.00 -188.00
Sitting height(cm)	86.48 ± 2.85	81.00 - 93.00
Weight (kg)	62.38 ± 10.01	45.00 - 95.00
Fat free mass(kg)	52.98 ± 6.53	41.29 - 75.36

IV (b) Exposed (males)

	Mean ± S.D	Range
Age (Yr.)	40.07 ± 9.91	20.00-57.00
Standing height(cm)	167.48 ± 6.33	151.00-184.00
Sitting height(cm)	86.28 ± 3.45	77.00-96.00
Weight (kg)	58.66 ± 8.92	44.00-84.00
Fat free mass(kg)	51.09 ± 6.16	32.98-67.63

IV (c) Non-exposed (females)

	Mean ± S.D.	Range
Age (yr.)	34.80 ± 8.45	21.00-57.00
Standing height(cm)	155.62 ± 5.09	139.00-173.00
Sitting height(cm)	81.17 ± 2.53	75.00-90.00
Weight (kg)	52.55 ± 8.94	37.00-89.00
Fat free mass (kg)	40.31 ± 5.91	30.03-56.39

Acute changes in ventilatory indices. In addition to pre shift measurments, post shift lung function measurements were also made on some volunteer exposed subjects. Values of lung function indices measured before work were compared with those measured immediately after the end of work. The mean differences between the two measured values are shown in Table V. From this table, it can be seen that exposure to cotton and tobacco dusts was found to cause significant reductions in FVC, FEV_1, MMFR and PEFR over the work shift. The effect of cement dust, however, showed significant reductions in only FVC and PEFR.

Acute changes in FEV_1 were also assessed using the classification of lung function changes resulting from exposure to vegetable dusts, established by a WHO study group (1983) shown below:

Classification	Changes
No effect	A consistent decline in FEV_1 of less than 5% or an increase in FEV_1 during the work shift.
Mild effect	A consistent decline of between 5-10% in FEV_1 during the work shift.
Moderate effect	A consistent decline of between 10-20% in FEV_1 during the work shift.
Severe effect	A decline of 20% or more in FEV_1 during the work shift.

according to this classification, respective mild and moderate effects on FEV_1 were observed among seventeen (47.22%) and five (13.89%) workers of the Yarn factory while only mild effect was observed in six (25%) workers of the Cigarette factory.

IV (d) Exposed (females)

	Mean ± S.D	Range
Age (Yr.)	36.00 ± 8.57	20.00-55.00
Standing height(cm)	156.24 ± 6.06	142.00-171.00
Sitting height(cm)	81.94 ± 3.32	75.00-88.00
Weight (Kg)	53.25 ± 8.94	36.00-75.00
Fat free mass(kg)	41.21 ± 5.39	28.36-56.14

Table V. Acute changes in Lung function values during work shift in some exposed subjects.

Factory	No. of Subjects	Statistic	Changes of Lung Function (Post shift - Pre shift)				
			FVC (ml)	FEV_1 (ml)	FEF (ml/sec)	MMFR (ml/sec)	PEFR (L/m)
Cement	21	Mean	-197.14	-62.86	428.57	27.62	-19.66
		S.D.	39.64	30.43	433.06	124.42	7.01
		t value	-4.97	-2.07	0.99	0.22	2.81
		Significance	**$P < 0.001$**	$P > 0.05$	$P > 0.05$	$P > 0.05$	**$P < 0.025$**
Cigarette	24	Mean	-71.67	-93.33	222.92	-259.17	-17.20
		S.D.	23.63	26.24	353.47	97.21	6.14
		t value	-3.03	-3.56	0.63	-2.67	-2.80
		Significance	**$P < 0.01$**	**$P < 0.01$**	$P > 0.05$	**$P < 0.025$**	**$P < 0.01$**
Yarn	36	Mean	-152.50	-178.61	-324.72	-435.00	-18.00
		S.D.	25.78	18.69	220.44	89.14	8.15
		t value	-5.92	-9.56	1.47	-4.88	-2.21
		Significance	**$P < 0.001$**	**$p < 0.001$**	$P > 0.05$	**$P < 0.001$**	**$P < 0.05$**

Chronic changes in ventilatory indices.

Exposed subjects compared with non-exposed subjects. Average lung function indices for all non-exposed and exposed (males and females) subjects are presented in Tables VI(a) and VI(b). As seen in Table VI(a) the arithmetic means of the lung function indices that are FEV_1, $FEV_1\%$, FEF, MMFR and PEFR in the male exposed groups were significantly lower ($P<0.001$) than in the non-exposed. Even though the mean values of FVC and MVV in the exposed subjects were found to be lower than in the non-exposed groups, the differences were not statistically significant ($P>0.05$). In contrast to the others, the mean value of MV in the exposed groups was found to be significantly higher ($P<0.05$) than it was in the non-exposed groups.

Significantly lower mean values in $FEV_1\%$ ($P<0.001$), FEF($P<0.05$) and MMFR ($P<0.05$) were observed among female exposed subjects than among non-exposed (Table VI(b)). Similarly, this table shows that the mean values of FEV_1 and PEFR were lower in the exposed groups than in the non-exposed, but the differences were not significant statistically ($P>0.05$). The mean values of FVC and MV were found to be slightly higher among the exposed subjects than in the non-exposed groups.

Table VI. Comparison of lung function values between non-exposed and exposed groups.

VI(a). Males: n=110 (non-exposed), n=110 (exposed).

		FVC	FEV_1	FEV_1%	FEF	MMFR	PEFR	MV	MVV
Non-exposed	Mean S.D.	4.57 0.71	3.91 0.65	85.62 6.15	7.82 1.75	4.96 1.47	607.42 75.51	10.81 3.39	135.33 34.46
Exposed	Mean S.D.	4.41 0.80	3.60 0.77	81.67 8.11	7.04 1.67	4.12 1.61	562.60 86.94	12.01 4.74	127.42 26.68
Significance		NS	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	P<0.05	NS

VI(b). Females: n= 101 (non-exposed), n= 101 (exposed)

		FVC	FEV_1	FEV_1%	FEF	MMFR	PEFR	MV	MVV
Non-exposed	mean S.D.	3.35 0.51	2.89 0.44	86.37 5.35	5.58 1.29	3.72 0.96	453.28 56.10	9.45 3.00	91.34 20.32
Exposed	Mean S.D.	3.40 0.53	2.82 0.46	83.19 6.31	5.21 1.38	3.38 1.03	445.22 71.69	9.67 3.34	87.04 20.78
Significance		NS	NS	P<0.001	P<0.05	P<0.05	NS	NS	NS

In order to assess the effect of dust exposure on the function of the lung in workers of every factory separately, matching of exposed subjects with the non-exposed subjects according to their age and height was made. For each man and woman in every factory, matches of the non-exposed ones were selected by their ages and heights within 5 years and 5 centimeters respectively. Age differences between subjects of every pair were within 2 years in 90 per cent of the cases and height differences were within 2 centimeters in 88 per cent of the cases, whereas differences in age and height in the remaining cases were within 3 to 5 years and 3 to 5 centimeters respectively. In most cases there were a number of matches for each exposed subject, and one of these then selected at random.

On the basis of this matching procedure, the mean values of pulmonary function indices for subjects of both sexes from every factory along with their corresponding non-exposed subjects are presented separately in Tables VII(a) through VII(e). In these tables, differences were seen in the mean pulmonary function indices between exposed subjects and their corresponding non-exposed subjects. Significantly lower mean values of $FEV_1\%$ ($P<0.05$), MMFR ($P<0.05$), FEF($P<0.01$) and PEFR($P<0.01$) were observed in male cotton workers than in their corresponding non-exposed subjects (Table VII(a)).

Table VII. Comparison of lung function values between matched non-exposed and exposed groups in each factory.

VII(a) Yarn factory (Males), n=25 (non-exposed), n=25 (exposed)

		Age (yr)	Height (cm)	FVC (L)	FEV_1 (L)	FEV_1 (%)	FEF (L/sec)	MMFR (L/sec)	PEFR (L/m)	MV (L/m)	MVV (L/m)
Non-exposed	Mean S.D.	42.16 6.63	166.72 4.28	4.38 0.57	3.69 0.45	84.48 6.02	7.88 1.61	4.52 1.13	602.25 49.22	10.01 3.38	131.42 31.74
Exposed	Mean S.D.	42.00 7.02	166.84 4.30	4.42 0.48	3.53 0.52	79.80 7.44	6.53 1.35	3.69 1.27	544.20 83.88	12.31 4.92	127.99 24.99
Significance		NS	NS	NS	NS	*	**	*	**	NS	NS

VII(b) Yarn factory (Females), n=56 (non-exposed), n=56 (exposed)

		Age (yr)	Height (cm)	FVC (L)	FEV_1 (L)	FEV_1 (%)	FEF (L/sec)	MMFR (L/sec)	PEFR (L/m)	MV (L/m)	MVV (L/m)
Non-exposed	Mean S.D.	36.59 8.67	155.73 4.82	3.32 0.47	2.86 0.40	86.36 5.35	5.67 1.39	3.72 0.92	455.77 50.33	9.88 3.01	90.21 17.91
Exposed	Mean S.D.	36.79 9.39	155.89 5.52	3.29 0.51	2.71 0.46	82.43 6.80	4.89 1.47	3.24 1.13	441.13 73.41	9.44 3.35	87.82 22.22
Significance		NS	NS	NS	NS	***	**	*	NS	NS	NS

* = $p < 0.05$ ** = $p < 0.01$ *** = $p < 0.001$

VII(c) Cigarette Factory (Males), n=26 (non-exposed), n=26 (exposed)

		Age (yr)	Height (cm)	FVC (L)	FEV_1 (L)	FEV_1 (%)	FEF (L/sec)	MMFR (L/sec)	PEFR (L/m)	MV (L/m)	MVV (L/m)
Non-exposed	Mean S.D.	41.00 8.80	167.92 6.57	4.48 0.75	3.79 0.62	85.00 6.29	7.90 1.80	4.69 1.36	612.39 71.21	10.18 3.17	140.42 25.78
Exposed	Mean S.D.	41.15 9.28	167.65 6.54	4.30 0.59	3.57 0.61	83.00 7.90	7.27 1.64	4.45 1.59	560.28 83.84	12.20 3.83	122.10 19.44
Significance		NS	NS	NS	NS	NS	NS	NS	*	*	**

VII(d) Cigarette factory (Females) n= 41 (non-exposed), n= 41 (exposed)

		Age (yr)	Height (cm)	FVC (L)	FEV_1 (L)	FEV_1 (%)	FEF (L/sec)	MMFR (L/sec)	PEFR (L/m)	MV (L/m)	MVV (L/m)
Non-exposed	Mean S.D.	34.44 6.69	156.51 5.41	3.38 0.54	2.93 0.41	87.20 5.13	5.73 1.20	3.90 0.91	450.93 52.92	9.60 2.74	91.92 21.31
Exposed	Mean S.D.	34.66 6.57	156.49 6.06	3.55 0.50	2.97 5.45	84.15 5.45	5.71 1.11	3.60 0.84	456.45 52.92	10.09 3.34	84.81 18.14
Significance		NS	NS	NS	NS	**	NS	NS	NS	NS	NS

* = $p < 0.05$ ** = $p < 0.01$

VII(e) Cement factory (Males) n=54 (non-exposed), n=54 (exposed)

		Age (yr)	Height (cm)	FVC (L)	FEV_1 (L)	FEV_1 (%)	FEF (L/sec)	MMFR (L/sec)	PEFR (L/m)	MV (L/m)	MVV (L/m)
Non-exposed	**Mean** S.D.	38.83 10.52	168.61 6.15	4.54 0.77	3.90 0.71	85.96 6.11	7.68 1.76	5.03 1.53	605.73 82.08	11.28 3.43	133.19 38.72
Exposed	Mean S.D.	38.89 10.98	168.17 6.30	4.51 0.97	3.66 0.91	81.20 8.43	7.22 1.78	4.12 1.76	573.24 90.41	12.09 5.18	130.51 30.49
Significance		NS	NS	NS	NS	**	NS	**	NS	NS	NS

** = $p < 0.01$

Similarly when compared with the non-exposed groups, lower mean values of FEV_1 and MVV and higher values of FVC and MV were observed in the same group of workers but the differences were not significant ($P>0.05$). Similar results were observed in the female cotton workers (Table VII(b)) with the exceptions that the difference exhibited in the mean values of PEFR in the exposed and non-exposed subjects was not significant and the mean value in FVC is slightly higher in the non-exposed than in the exposed groups.

Even though mean values of the lung function indices recorded among the exposed male and female workers of the cigarette factory were lower than those observed among their corresponding non-exposed subjects, significant differences were observed only in the mean values of PEFR and MV ($p<0.05$) and MVV ($p<0.01$) in men and $FEV_1\%$ ($p<0.01$) in women (Tables VII(c) and VII(d))

Furthermore, mean values of all lung function parameters, except MV, were observed to be lower in cement workers (all males) than in the non-exposed subjects (Table VII(e)). The differences, however, were significant in only $FEV_1\%$ and MMFR ($p<0.01$). The mean value of MV was slightly higher in these workers than in the non-exposed groups.

As noted earlier, lung function data of the non-exposed groups were used in the establishment of regression equations of ventilatory indices, which could serve as the prediction formulae for the exposed groups (study subjects). Anthropometric measurements which showed the highest correlations with lung function indices, were used as independent variables in the establishment of regression equations. To see the correlations between variables, the product-moment correlation (r) matrices were developed based on the thirteen parameters available (for males and females separately) out of which eight of them were derived from pulmonary function testing while the other five were different anthropometric measurements. Each of the thirteen measurements was correlated with the other twelve measurements. These correlation matrices, for males and females, are shown in Appendix II.

It can be seen from these matrices that there were high correlations ($r \geq 0.30$ or $r \leq -0.30$) between some anthropometric characteristics and some ventilatory indices. High negative correlations were demonstrated between age and most of the ventilatory indices viz., FVC, FEV_1, $FEV_1\%$, MMFR, PEFR and MVV in male subjects and FVC, FEV_1 and MVV in female subjects. Likewise, both standing and sitting heights demonstrated higher positive correlations with FVC and FEV_1 in both male and female subjects. Furthermore, fat free mass (FFM) was also found to show marked positive correlation with FVC in both sexes. Because they showed high correlations, age, standing height and FFM were chosen in the development of prediction formulae for various lung function indices. In both tables of the correlation matrix, it is observed that standing height showed a higher correlations with FVC and FEV_1 than did the sitting

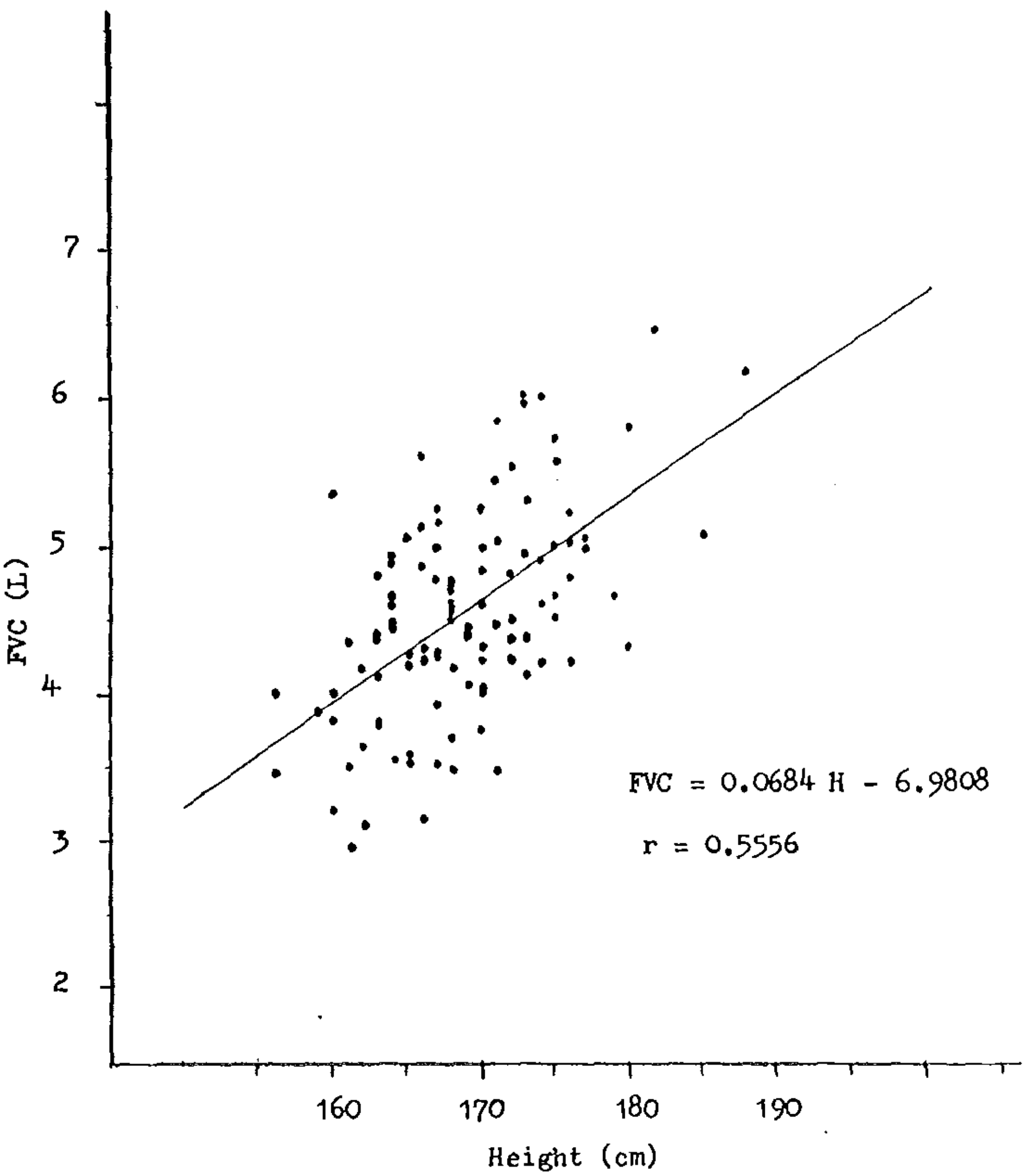


Fig. VIII: Linear regression of FVC on standing height in the 110 non-exposed males

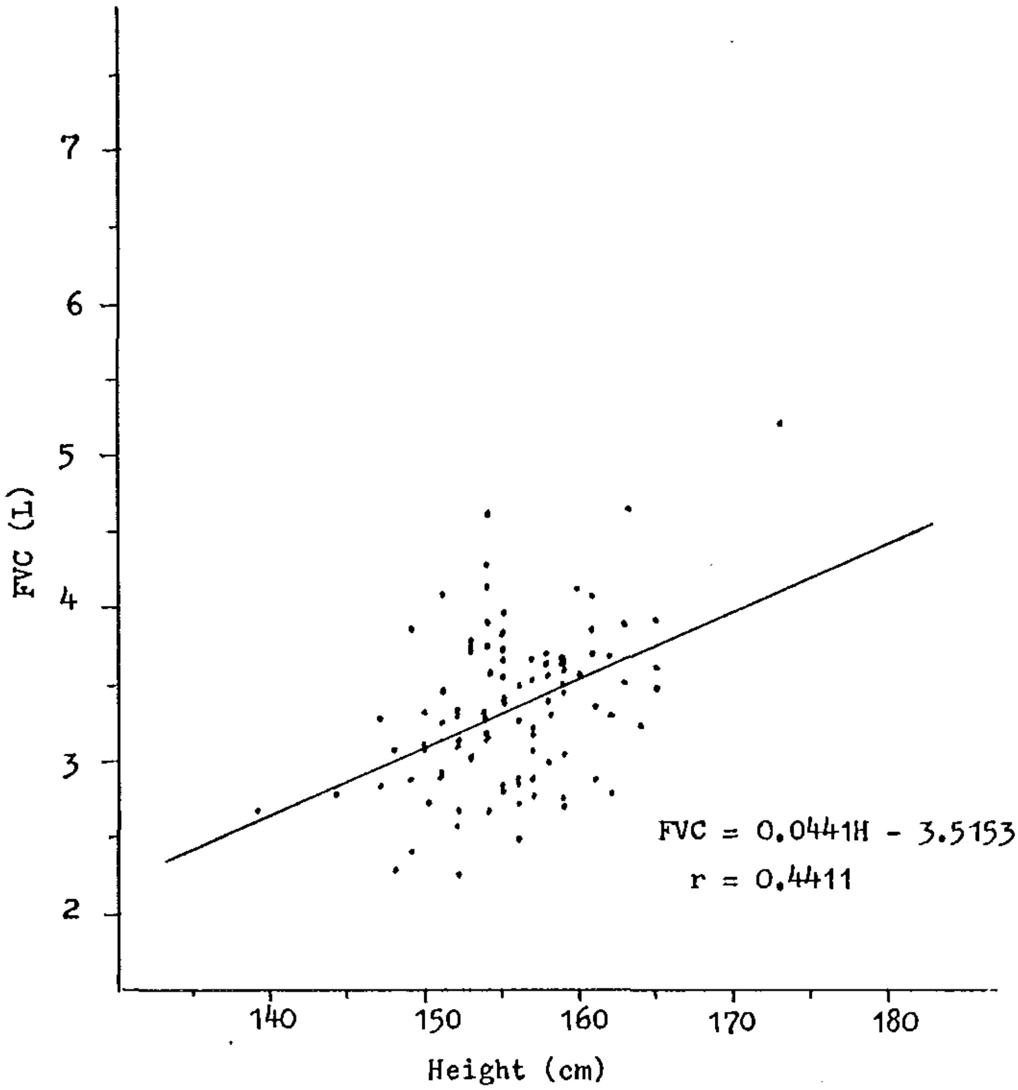


Fig. IX: Linear regression of FVC on standing height in 101 non-exposed females

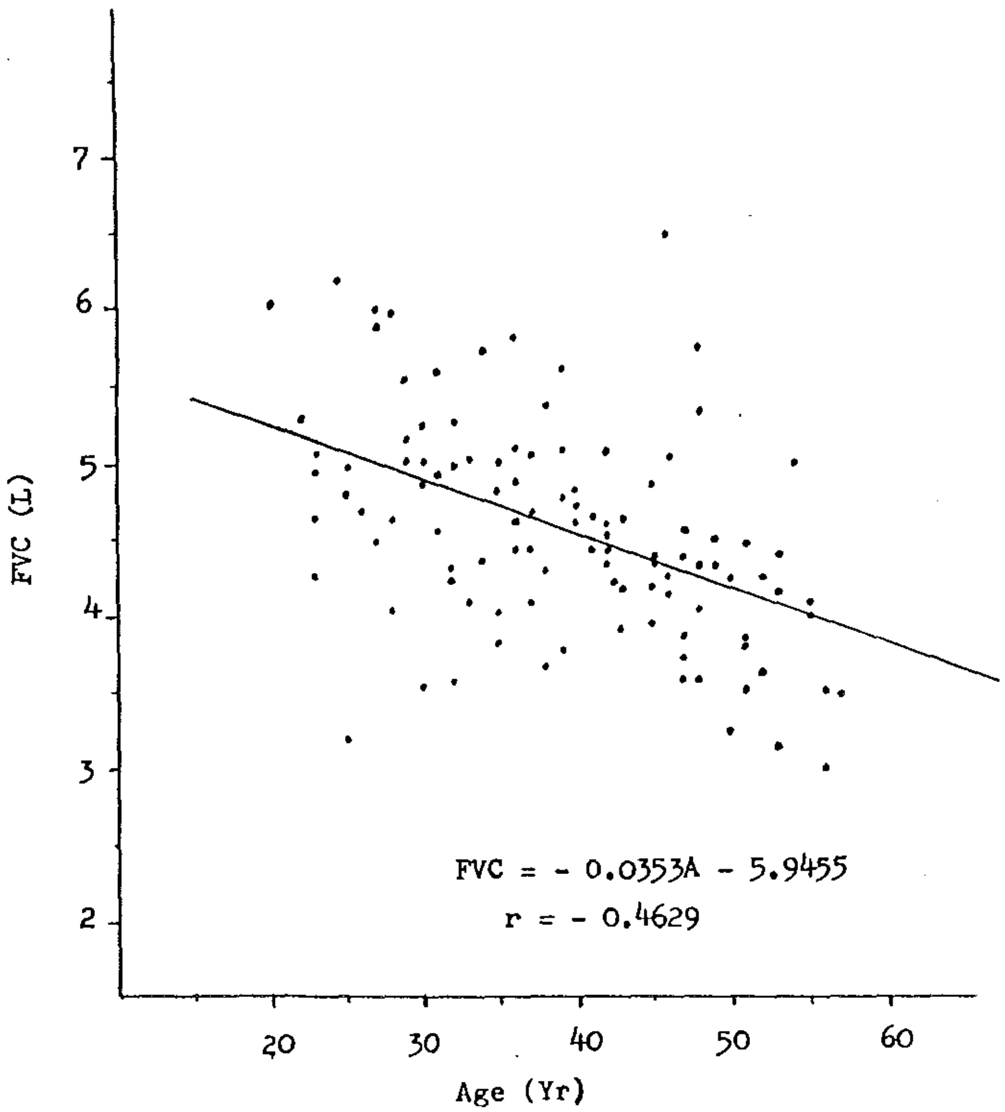


Fig. X: Linear regression of FVC on age in the 110 non-exposed males

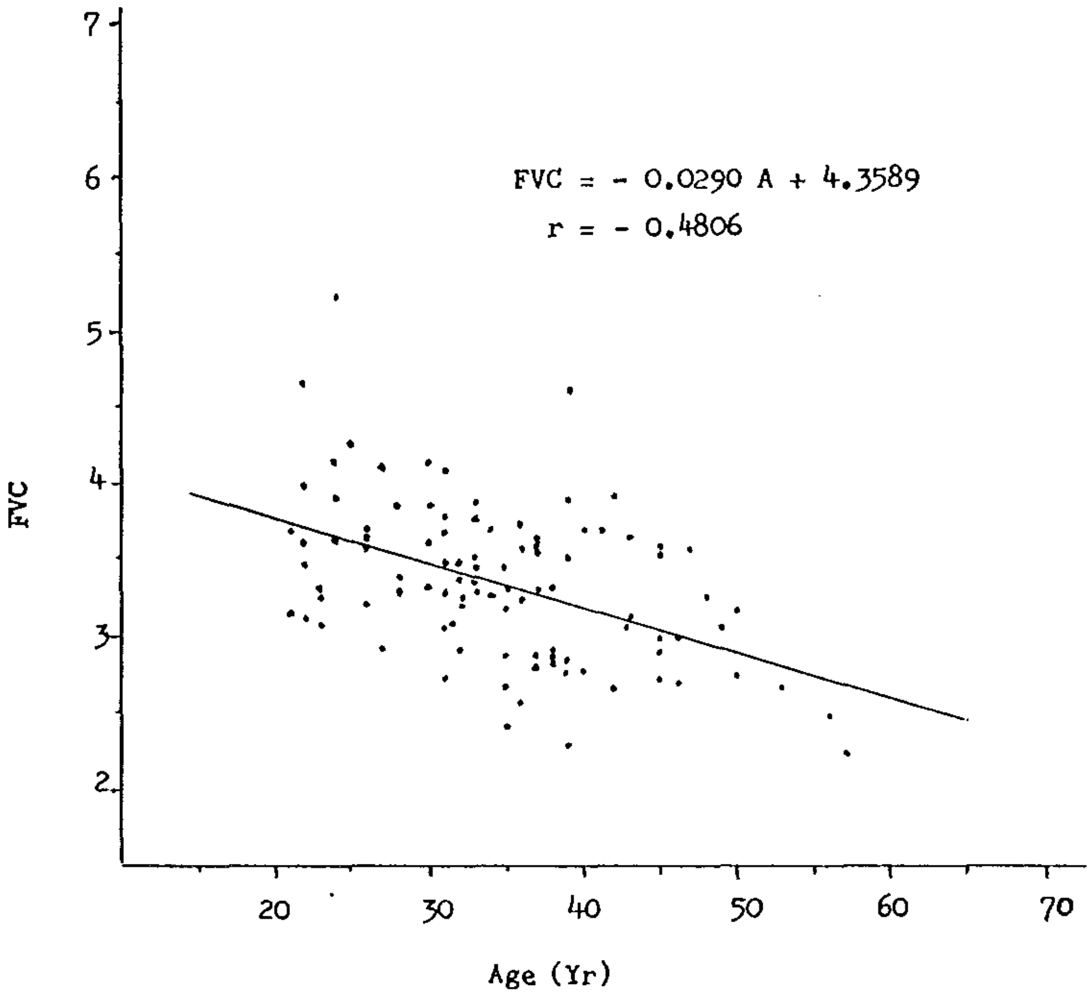


Fig. XI: Linear regression of FVC on age in the 101 non-exposed females

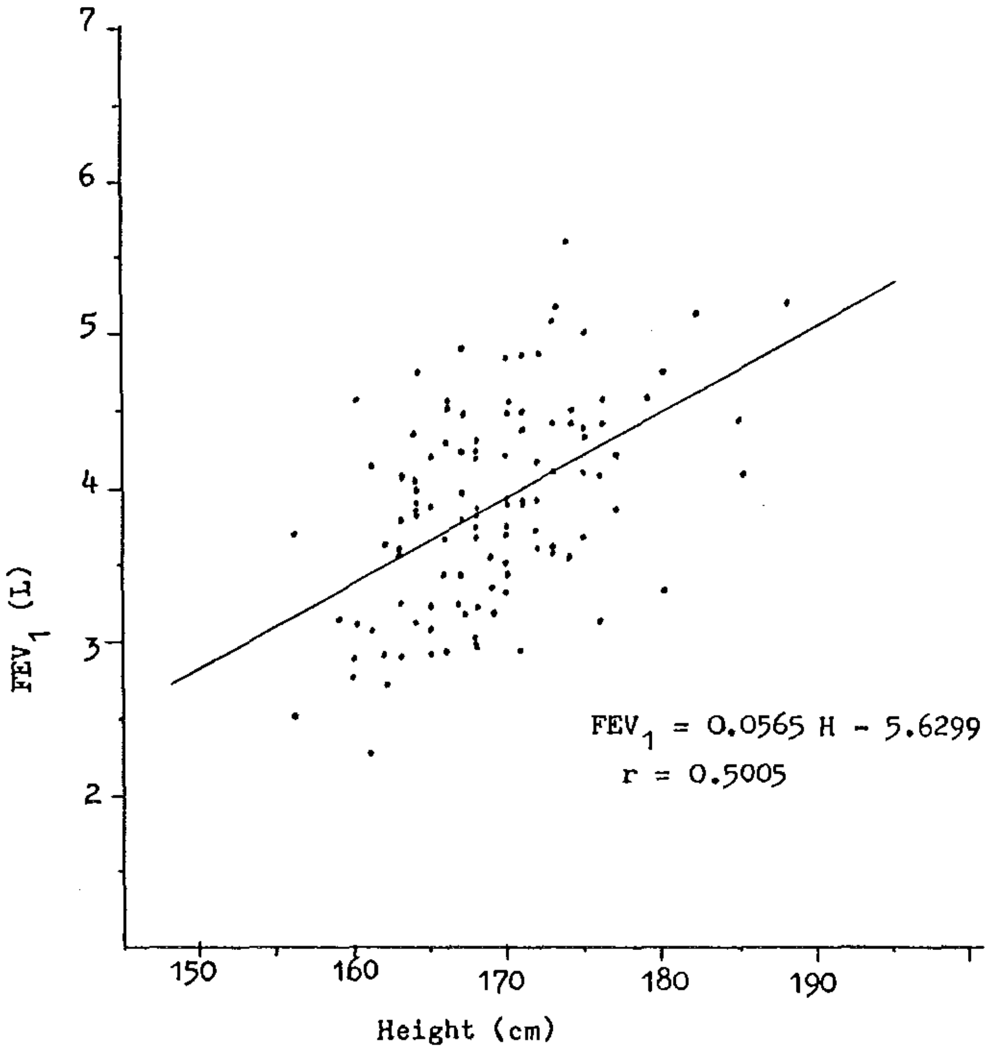


Fig. XII: Linear regression of FEV_1 on standing height in 110 non-exposed males

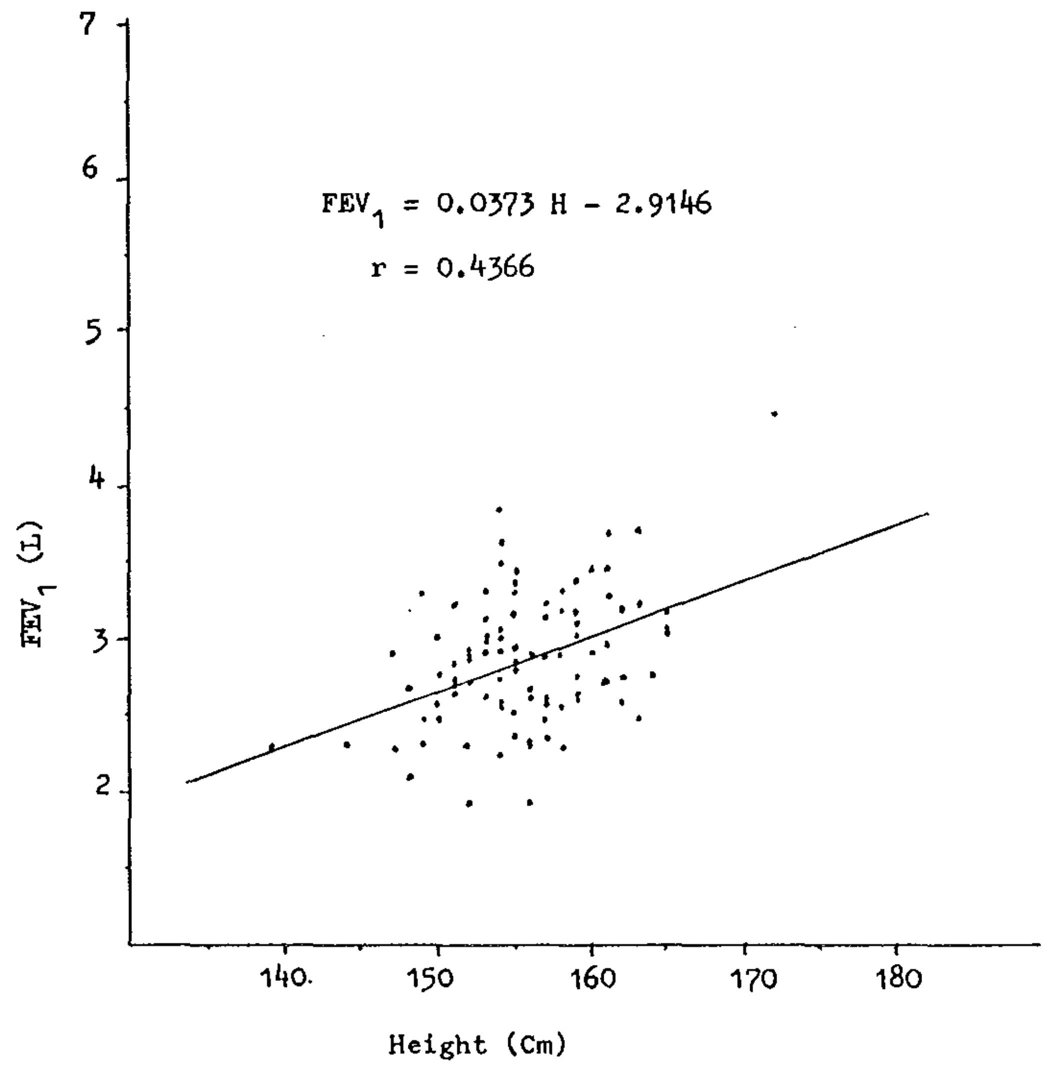


Fig. XIII: Linear regression of FEV_1 on standing height in the 101 non-exposed females

Table VIII. Regression equations of ventilatory induces for both male and female non-exposed subjects.

Sex	Ventilatory indices	Height (cm)	Age (yr)	FFM	Constant	R or r	S.E.E.
Male	FVC	0.0375	-0.0357	0.0366	-2.3110	0.7126	0.5065
	FEV1	0.0421	-0.0391	-	-1.6705	0.7393	0.4436
	FEV1%	-	-0.0392	-	98.8351	-0.5146	5.2944
	MMFR	-	-0.0861	-	8.3156	-0.5456	1.2381
	PEFR	-	-3.9860	-	762.6188	-0.4922	66.0329
	MVV	-	-1.8314	-	206.6370	-0.4956	30.0657
Female	FVC	0.0341	-0.0276	0.0130	-1.5208	0.6449	0.3953
	FEV_1	0.0343	-0.0255	-	-1.5626	0.6596	0.3304
	MVV	-	-0.7383	-	117.0362	-0.3069	19.4386

affected ones. Thus, using this criterion, ten (17.86%), six (10.71%) and five (8.39%) of the fifty six (56) cement (all males) workers were found to show markedly lower (<2 S.E.E.) values in FEV_1%, MMFR and PEFR respectively (Table IX). Out of 27 male workers, in the cigarette factory, three (11.11%) of them were found to show remarkable reductions in FEV_1, three (11.11%) in FEV_1% and again three in MMER and five (18.52%) in PEFR. Likewise, out of 27 male cotton workers, seven (25.93%), four(14.82%) and again four (14.82%) of them were found to show marked reductions in FEV_1%, MMFR and PEFR values respectively. Seven (11.76%) female cotton workers were also found to show highly reduced values from their predicted values in FEV_1 (Table IX).

According to the classification established by a WHO (1983) study group, workers on vegetable dusts with FEV_1 equal or greater than 80% of the predicted values are considered to have no chronic ventilatory changes, those with FEV_1 from 60-79% are considered to develop mild to moderate effects and those with FEV_1 less than 60% have severe effects.

In the present study, chronic effects of dust particles on FEV_1 were observed to be mild to moderate in five (18.52%) male workers of the cigarette factory. Similar effects were also observed in four (14.81%) male and ten (16.67%) female workers in the Yarn factory.

Table IX. Proportions of exposed subjects with ventilatory indices lower than the predicted values by more than 2 S.E.E.

Factory	Sex	n	Lung Function	No. of affected subjects	Percent
Cement	Male	56	FVC	2	3.57
			FEV_1	2	3.57
			$FEV_1\%$	10	**17.86**
			MMFR	6	**10.71**
			PEFR	5	**8.39**
			MVV	2	3.57
Cigarette	Male	27	FVC	1	3.70
			FEV_1	3	**11.11**
			$FEV_1\%$	3	**11.11**
			MMFR	3	**11.11**
			PEFR	5	**18.52**
			MVV	1	3.70
	Female	41	FVC	1	2.44
			FEV_1	-	-
			MVV	1	2.44
Yarn	Male	27	FVC	1	3.70
			FEV_1	1	3.70
			$FEV_1\%$	7	**25.93**
			MMFR	4	**14.82**
			PEFR	4	**14.82**
			MVV	-	-
	Female	60	FVC	1	1.67
			FEV_1	7	**11.67**
			MVV	1	1.67

Ventilatory indices and dust concentrations.

Respirable dust concentrations recorded in different sections of every factory are shown in Table X. The highest concentration of respirable dust particles was recorded in the blow room and the lowest in the packing section of Adey Abeba Yarn Factory. Likewise, relatively higher concentration was recorded in the blending section and the lower amount recorded in packing section of Addis Ababa Cigarette Factory. Dust concentration measurements were conducted in only packing and rotary kiln sections of Addis Ababa Cement Factory. Other sections viz., quarry, homogenization, cement mill and raw mill were not found to be functional during this survey. The amount of dust recorded in packing section was much more greater than the concentration recorded in rotary kiln.

Comparisons of mean percentage of the predicted lung function values were made between workers in areas with relatively higher dust concentration and workers in areas with lower dust concentration (Tables XI(a) through XI(e)).

Table X. Mean dust concentrations in various sections of each factory

Factory	Section	No. of Samples	Mean Concentration (mg/m^3) ±S.D.
Yarn	Blow room	4	4.23 ± 3.51
	Card room	4	1.78 ± 1.35
	Drawing & Roving	5	0.79 ± 0.20
	Ring	4	0.70 ± 0.58
	Winding	4	0.64 ± 0.42
	Reeling	4	0.50 ± 0.40
	Packing	4	0.42 ± 0.55
Cigarette	Blending	5	1.83 ± 1.99
	Making	4	0.48 ± 0.31
	Packing	3	0.29 ± 0.11
Cement	Rotary kiln	4	3.24 ± 1.62
	Packing	7	43.1 ± 35.33

These comparisons were made in each factory by taking percentage of predicted lung function values of those who didn't change their working sections during the course of their employment.

In Tables XI(a) through XI(e), it can be seen that lower mean percentage of the predicted lung function values were recorded in workers of relatively higher dust concentration areas than in those working in places with lower dust concentration, even though these differences were not found to be significant ($P>0.05$) except in cement factory where significantly lower ($P<0.05$) mean percentage of the predicted value in $FEV_1\%$ was recorded.

Duration of exposure and pulmonary function.

The relationship between lung function impairment and duration of exposure to dust was assessed by calculating the product-moment correlation values between each ventilatory index for study subjects and their exposure time in years. By doing this, inverse relationships between duration of exposure and values of pulmonary function indices in both sexes of the study subjects were noted. These are presented in Table XII for each sex separately. The observed inverse correlations were not found to be strong in female subjects ($r \geq -0.30$) (Table XII) while they were strong in the male subjects ($r \leq -0.30$) particularly in FVC , FEV_1, $FEV_1\%$ and MMFR (Table XII).

Table XI. Differences in the mean percentages of predicted lung function values of subjects in low and high dust concentrations.

XI(a) Yarn factory (males)

Section	1) Packing 2) Drawing & Roving	1) Blow room 2) card room	
n	10	15	Signi-ficance
Concentration Range (mg/m^3)	0.42 - 0.79	1.78 - 4.23	
D.exp. in Yr.* (mean±S.D)	14.17 ± 6.50	14.72 ± 4.41	NS
FVC (,, ,,)	105.10 ± 13.54	101.93 ± 12.78	NS
FEV_1 (,, ,,)	96.00 ± 14.25	93.53 ± 14.33	NS
FEV_1% (,, ,,)	95.10 ± 8.57	94.20 ± 9.17	NS
MMFR (,, ,,)	79.10 ± 27.86	77.20 ± 25.49	NS
PEFR (,, ,,)	93.00 ± 16.03	90.73 ± 15.24	NS
MVV (,, ,,)	99.30 ± 23.47	99.46 ± 23.21	NS

* Duration of exposure in year.

XI (b) Yarn factory (females)

Section	1) Winding 2) Reeling 3) Packing	1) Card room 2) Drawing & Roving	
n	12	12	Signi-ficance
Concentration range (mg/m^3)	0.42 - 0.64	0.79 - 1.78	
D.exp. in Yr.			
FVC(mean±S.D)	13.23 ± 7.58	12.70 ± 7.65	NS
FEV_1 (,, ,,)	106.00 ± 13.97	99.50 ± 10.04	NS
MVV (,, ,,)	98.25 ± 13.88	96.42 ± 10.73	NS
	111.58 ± 24.35	97.33 ± 23.33	NS

XI (c). Cigarette factory (males)

Section	Blending	1) Packing 2) Making	Signi-ficance
n	12	14	
Concentration range (mg/m³)	1.83	0.29 - 0.48	
D.exp. in Yr. (mean±S.D)	17.63 ± 7.17	16.09 ± 7.83	Ns
FVC (,, ,,)	97.50 ± 7.31	95.50 ± 11.18	NS
FEV_1(,, ,,)	93.42 ± 9.69	95.14 ± 14.99	NS
FEV_1%(,, ,,)	95.92 ± 9.16	99.79 ± 7.30	NS
MMFR (,, ,,)	90.08 ± 36.42	95.79 ± 35.45	NS
PEFR (,, ,,)	94.67 ± 11.11	91.00 ± 16.95	NS
MVV (,, ,,)	94.92 ± 19.69	94.50 ± 24.88	NS

XI (d). Cigarette factory (females)

Section	Packing	Making	Signi-ficance
n	16	17	
Concentration mean (mg/m³)	0.29	0.48	
D.exp. in Yr. (mean±S.D)	10.68 ± 5.19	10.78 ± 7.67	NS
FVC (,, ,,)	109.44 ± 15.88	101.76 ± 12.46	NS
FEV_1(,, ,,)	105.19 ± 12.03	100.00 ± 10.76	NS
MVV (,, ,,)	93.13 ± 17.09	93.12 ± 20.59	NS

XI (e). Cement Factory (males)

Section	Rotary kiln	Packing	Signi-ficance
n	12	16	
Concentration mean (mg/m^3)	3.24	43.10	
D.exp. in Yr. (mean±S.D)	14.51 ± 11.68	8.55 ± 3.93	NS
FVC (,, ,,)	101.25 ± 12.15	103.94 ± 16.23	NS
FEV_1 (,, ,,)	97.83 ± 13.97	91.31 ± 16.95	NS
FEV_1% (,, ,,)	98.08 ± 6.52	89.81 ± 10.68	$p<0.05$
MMFR (,, ,,)	90.58 ± 24.31	73.88 ± 29.63	NS
PEFR (,, ,,)	98.08 ± 11.27	91.94 ± 14.31	NS
MVV (,, ,,)	104.00 ± 25.31	93.00 ± 20.86	NS

Table XII. Correlation coefficients between duration of exposure and different indices of lung function.

	Male exposed subjects	Female exposed subjects
FVC	**-0.35**	-0.17
FEV_1	**-0.46**	-0.18
FEV_1%	**-0.33**	-0.06
FEF	-0.19	0.03
MMFR	**-0.43**	-0.14
PEFR	-0.25	-0.12
MV	0.00	0.05
MVV	-0.21	-0.05

D I S C U S S I O N

The results of the present study show that the prevalence rates of all considered respiratory symptoms viz., chronic cough, chronic bronchitis and bronchial asthma, among cement and cotton workers are found to be significantly higher than they are in the non-exposed groups (Table III). Similar to the present findings, Kalacic (1973) reported that there were significant prevalences of various respiratory symptoms including chronic cough and chronic bronchitis among cement workers in Yugoslavia. In addition, persistent cough and chronic bronchitis were reported to be highly prevalent among cotton workers in the same country (Zuskin & Valic, 1972). Similarly, Mentesinot (1988) reported the prevalences of chronic bronchitis and bronchial asthma in a good number of Bahir Dar Textile workers in Ethiopia. Excessive prevalences of chronic bronchitis among cotton workers had also been reported by other investigators from various countries (Schilling, 1964; Molyneux & Tombleson, 1970; Fox *et al.*, 1973; Berry *et al.*, 1974). In contrast to cement and cotton, tobacco workers, in the present study, are found to demonstrate no significant difference in the prevalences of chronic bronchitis and bronchial asthma when compared with the non-exposed groups. Likewise, Valic *et al.* (1976) found that the prevalence of chronic bronchitis among female tobacco workers showed no difference when compared with the prevalence among the non-exposed groups.

Records of lung function parameters are known to provide useful information about the status of airways calibre (both large and small airways), lung volumes and respiratory muscles. FVC reflects variation in effective lung volume; FEV_1% and FEF reflect the status of the calibre of large airways and MMFR the calibre of medium-sized airways. FEV_1 is a hybrid variable depending on both lung size and airway calibre. PEFR is an index of mechanical problems, but is largely nonspecific. MVV measures the status of the respiratory muscles, the compliance of the lung-thorax system, and the resistance offered by the airways and tissues (Ruppel, 1979; Jain & Patrick, 1981).

In the present study, the acute decrease in FVC, FEV_1, MMFR and PEFR during the work shift were recorded in some volunteer study subjects from cotton and cigarette factories. Similar results were also observed in some cement workers, but only in FVC and PEFR (Table V) .

The finding that FVC, FEV_1, and MMFR are reduced over the work shift in cotton workers is in agreement with the results of Valic and Zuskin (1977). Similarly, the acute reduction in FEV_1 among cotton workers reported by Khogali (1969) Zuskin and Valic (1972), Fox *et al.* (1973), Merchant *et al.*(1974) and Zuskin *et al.*(1976) is in accordance with our results. The acute changes in FVC and FEV_1 among tobacco workers, in the present study, is also found to be in agreement with the finding of Valic and his associates (1976) who showed this result by conducting a study on 318 female tobacco workers.

It is also noted that the mean values in $FEV_1\%$, FEF and MMFR among all exposed subjects of both sexes (Table VI(a) and VI(b)) and in PEFR among all male subjects are significantly lower than they are in the non-exposed groups. These findings may probably suggest that the effects of dust particles in this study are more prominent on the calibre of the medium-sized and larger airways.

In addition to this, the observation that FEV_1 is significantly reduced in male exposed subjects than in the non-exposed ones without the occurrence of significant difference in FVC also suggests that the effect of dusts in this study reduces airway calibre.

The findings of significant reductions in the mean values of MMFR and $FEV_1\%$ among cotton workers of both sexes (Table VII (a) and VII(b)), in the present study, are in accordance with the findings of Zuskin and Valic (1972) and Zuskin *et al.* (1976) respectively. When compared with the non-exposed subjects, there is a lower mean value recorded in FEV_1/FVC ratio among cement workers. This finding is also in agreement with the finding of Kalacic (1973).

This study shows that male tobacco workers had significantly lower mean values in PEFR (Table VII(c)) and female tobacco workers in $FEV_1\%$ (Table VII(d)) than in their corresponding non-exposed groups. This may suggest that nonspecific and obstructive problems existed among male and female tobacco workers respectively. Even though it is observed that male tobacco workers showed nonspecific respiratory problems on the whole, there are appreciable number of them who showed values lower than their predicted in FEV_1, $FEV_1\%$ and MMFR - ventilatory indices showing obstruction problems (Table IX).

Among the limited studies on the effect of tobacco dust, the report of Valic and his collaborates (1976) is the one which demonstrates the absence of chronic lung function changes in female tobacco workers when compared with their predicted values. But in contrast to their findings, it is observed in the present study, that there is significant reduction in the mean value of $FEV_1\%$ among female tobacco workers (Table VII(d)). In addition, about 11% of male tobacco workers showed FEV_1, $FEV_1\%$ and MMFR measured values that are significantly lower than the predicted values (Table IX).

It is also observed that the mean value of MV (12.20 L/min) is found to be higher in tobacco male workers than in the corresponding non-exposed subjects (10.18 L/min) (Table VII (c)). The normal value of MV, according to Ruppel (1979), is in the range of 5 to 10 L/min. This author also stated that the rise in minute ventilation occurs mainly in response to hypoxia, hypercarbia and acidosis. Even though the reason for the raised level of MV in male tobacco workers beyond the normal range and above the mean value attained by the controls is not clear, an assumption can be made that the aforementioned factors could be acquired by these workers due to various cases including exposure to dust.

Mean values in MVV have been recorded to be significantly lower in the same group of workers (Table VI (c)) than in their corresponding non-exposed subjects. Since the manoeuvre of MVV measurement is difficult and considerably dependent on the subject's full cooperation, it is difficult to conclude that differences in MVV observed between the two groups is wholly attributable to the dust.

Possible effects of dust particles on ventilatory function were also assessed on the basis of the differences between measured and predicted values in FVC, FEV_1, FEV_1%, MMFR, PEFR and MVV for males and FVC, FEV_1, and MVV for females. The proportions of exposed workers who showed lower values in the aforementioned ventilatory indices, seem to show differences (not statistically significant) among factories (Table IX). When compared with those in cigarette and cement factories, higher proportions of male workers in yarn factory were found to show values in FEV_1 and MMFR that are lower than the predicted values (25.93% in FEV_1% and 14.82% in MMFR). Larger proportion of female workers in Yarn factory (11.67%) were also found to show significantly lower FEV_1 values than the predicted when compared with that of females in cigarette factory. On the other hand, larger proportion of cement workers (17.86%) were observed to show marked reduction in FEV_1% value than tobacco workers (11.11%). Relatively higher proportion of male cigarette workers were also found to show markedly lower PEFR value.

The effect of dust concentration on the function of the lung is clearly seen only in cement workers (Table XI (e)). Significant differences ($P<0.05$) in the mean percentage predicted lung function values between those working in a relatively high and low dust concentration areas were recorded among cement workers in FEV_1%. Differences were also observed in the rest of the cases, but they are not statistically significant. The inverse relationship between lung function values and the concentration of dust, particularly for cotton, had been reported by many investigators from other countries (Gilson *et al.*, 1962; Fox *et al.*, 1973; Rylander *et al.*, 1979). Similar results have also been reported in Ethiopian cotton workers by Mintesinot (1988).

The inverse relationship between duration of exposure to dust and many of the lung function indices was observed in both male and female exposed subjects (Table XII). These relationships were found to be high ($r \leq -0.30$) in FVC, FEV_1, FEV_1%, and MMFR for men and they were found to be very low ($0 > r \geq -0.30$) for women. The inverse relationship found between exposure time and lung function values is difficult to interpret. Since age and duration of exposure were found to be directly and strongly correlated in both male and female subjects ($r= 0.73$ for men and $r= 0.76$ for women), it is difficult to suggest that the observed reductions of ventilatory indices are whether attributable to aging or increasing duration of exposure.

Dust concentrations in different working conditions have been reported by several investigators from various countries.

For instance in England, the presence of 3.10 mg/m^3 coarse and 1.20 mg/m^3 medium-sized cotton dust particles in a certain textile factory was recorded by Molyneux and Tombleson (1970). Cotton dust levels varying from 1.15 mg/m^3 to 4.80 mg/m^3 were recorded by Fox and his associates (1973) in the same country. In Nigeria, total cotton dust concentration up to 14.94 mg/m^3 was recorded by Oleru (1980) in 1979. Concentration values of 4.18 mg/m^3 and 1.44 mg/m^3 for total and respirable fractions, respectively, were also recorded in Yugoslavia (Zuskin & Valic, 1972). Tobacco dust concentrations ranging from 0.90 to 27.50 mg/m^3 for total dust and from 0.30 to 3.60 mg/m^3 for respirable dust were documented in the same country (Valic *et al.*, 1976). Dust levels ranging from 26 to 114 mg/m^3 were measured in quarries and cement works in different countries (Prodan, 1983).

The concentrations of dust particles in the present study (Table X) are found to be similar in magnitude to dust concentrations recorded in countries mentioned above. Dust of such concentrations in the working environment were found to cause respiratory problems on workers. For instance, significantly reduced values in FVC, FEV_1 and PEFR over the work shift and remarkably lower mean percentage of predicted values in FEV_1 were recorded in Yugoslavian cotton workers (Zuskin & Valic, 1972). Chronic changes in FVC and FEV_1 were also recorded in Nigerian workers exposed to cotton dust (Oleru, 1980). Likewise, in the present study, the adverse effect of dusts on the function of the lung is found to be considerable. Significantly reduced level in FEV_1, FEV_1%, FEF, MMFR and PEFR has been recorded among the exposed groups on the whole and remarkable acute fall in FVC, FEV_1, MMFR and PEFR in both cotton and tobacco workers and acute reductions in FVC and PEFR among cement workers were observed.

To minimize the effects of dust particles on the health of workers, their concentrations in the working environment should be reduced to international standards. Since there is a lack of materials and finance for conducting toxicological investigations and lack of available human data, the establishment of permissible levels is very difficult for many countries. Hence many of them adopt threshold limit values for dusts and other hazardous agents, established by some authorities like American Conference of Governmental Industrial Hygienists (ACGIH) and World Health Organization (WHO). According to ACGIH (1988 - 1989), the threshold limit value for total cotton dust is 0.20 mg/m^3. This standard is also recommended by WHO (1983). The threshold limit value for cement total dust is 10 mg/m^3 according to ACGIH. The standard for tobacco dust is not established by either ACGIH or WHO.

When compared with the permissible limits set by these two authorities, dust levels of the present study in both cotton and cement factories are very high even at a respirable fraction.

C O N C L U S I O N

In this study, it has been tried to assess the effect of occupational dusts on the respiratory system of the exposed workers. On the basis of the dust type to which they are exposed, three groups of nonsmoking workers were examined on different occasions, together with corresponding non-exposed groups. Anthropometric measurements, lung function tests and administration of standard questionnaire on respiratory symptoms (British Medical Research Council) were carried out on each subject. In addition to these, dust concentration measurements were conducted in each working place. Analysis of the results of each measurement were made and the following conclusive findings are listed.

Naturally acquired respiratory symptoms are found to be more frequent in workers exposed to occupational dusts than they are in the general population.

The effect of tobacco dust in producing respiratory symptoms seem to be less marked than the effects caused by dusts of cotton and cement.

The dust types considered in the present study have prominent effects on the calibre of both large and medium-sized airways.

The three dust types considered in this survey are found to be causing acute reductions of lung volumes and capacities.

In contrast to cotton and tobacco dusts, cement dust was not found to cause remarkable acute reduction in

MMFR - an index that shows the status of medium-sized airways. This probably indicates that cement dust cannot produce an acute effect on the calibre of medium-sized airways.

The effect of dust concentration on the values of lung function indices, particularly on $FEV_1\%$, is found to be relatively more prominent in workers exposed to cement dust.

The respirable dust concentrations recorded in yarn and cement factories are found to be high in comparison with the threshold limit values for total dusts recommended by ACGIH and WHO.

Duration of exposure showed negative correlation with many of the pulmonary function parameters. High correlations ($r \leq -0.30$) were observed particularly in male exposed subjects. Since age may have contribution to these relationships, it is difficult to conclude that exposure time and indices of lung function showed apparent relationship in the present study. Further investigations are needed to clarify the nature of the association observed more precisely.

RECOMMENDATIONS

As it has been observed in the present study, the respirable dust levels in two of the three factories are found to be high when compared with internationally accepted threshold limit values for mon-respirable and respirable dusts put together. The occurrence of respiratory impairments emanating from the relatively high dust concentration of the three factories is reflected by reduced levels of lung function indices. In order to minimize the effect of dusts on the respiratory system of the workers, the following recommendations are made:

1. Preventive measures, such as installation of proper systems of ventilation and the provision of appropriate personal protective devices should be made to minimize exposure to atmospheric dusts.

2. Pre-employment medical examinations on the respiratory system should be made to place workers in appropriate work sites. It is also helpful to have a follow-up on the health status of the exposed workers.

3. Periodic medical examinations (including lung function tests) should also be made to detect severe acute responses to dust as well as early signs of chronic lung disease and irriversible loss of lung function.

4. Creation of awareness among the workers through safety training, seminars and posters is also useful to minimize the risk of exposure.

A P P E N D I C E S

Appendix I. Descriptions oflung function parameters considered in the present study.

1. **Forced vital capacity (FVC)** is the maximum volume of air, which can be expelled as rapidly and completely as possible after maximum inspiration, exerting maximum effort (Gandevia & Hugh-Jones, 1957; Cotes, 1979). Normal values of FVC largely depend on height and age of individuals. Ruppel (1979) stated that decreased FVC is common to restrictive diseases such as pulmonary fibrosis, as well as obstructive processes such as emphysema and asthma.

2. **Forced expiratory volume (FEV).** It is the volume of air which can be expelled from the airways and lungs over a given time interval during the performance of forced vital capacity manoeuvre (Cotes, 1979). The commonly used time intervals stated as subscripts to FEV are 0.5-, 0.75-, 1-, 2- and 3-seconds. They can be written as $FEV_{0.5}$, $FEV_{0.75}$, FEV_1, FEV_2 and FEV_3. Of these, forced expiratory volume in one-second (FEV_1) is the most extensively used parameter. According to Cotes (1979), the FEV_1 in healthy adult males, depending on their age and size, is in the range of 1.2 to 5.7 liters. In females the range is from 0.8 to 4.2 liters.

3. **The one-second Forced Expiratory Volume percent (FEV_1%)** is an expression of FEV_1 as a percentage of the measured forced vital capacity. The ratio in adults, depending on their age, is normally in the range from 51% to 97% in males and 59% to 93% in females (Cotes, 1992). Patients with obstructive diseases are known to show reduced FEV_1% and in most cases, patients with restrictive diseases ofteng show normal FEV_1%, since their FVC volume is not usually normal (Ruppel, 1979).

4. **Forced Expiratory Flow ($FEF_{200-1200}$)** is an average rate of air flow from a given one-liter volume segment in the early part of a forced expiratory spirogram. The most commonly used volume segment in adults is between 200 ml and 1200 ml. Because of inertia of the lung-thorax system, the initial 200 ml of volume is usually expired at a slower rate and hence the disregard of the first 200 ml volume in the measurement of FEF. This index is very important in showing the flow characteristics of the large airways. The average rate of airflow in this index for a healthy young man is 6 to 7 L/sec (Ruppel, 1979).

5. **Maximum Midexpiratory Flow (MMFR)** is an average rate of air flow during the middle two quarters of the volume segment of the forced expiratory spirogram, i.e. from $V_{25\%}$ to $V_{75\%}$ of the FVC and it can be written as $FEF_{25\%-75\%}$. MMFR is normally somewhat slower than the $FEF_{200-1200}$ and it is indicative of the status of medium-sized airways (Ruppel, 1979). According to Leuallen and Fowler (1955), the mean value of MMFR is 4.5 liters per second in men and 3.7 liters per second in women. A decrease occurs after 50 years of age in both sexes.

6. **Peak Expiratory Flow Rate (PEFR)** is the maximum flow rate of air that could be attained at any time during a forced expiration manoeuvre started from a position of full inspiration. It is usually measured with Wright Peak Flow Meter (Tinker, 1961; Arnott, 1962; Cotes, 1979). Decreased peak flow rate is indicative of mechanical problem but is largely non specific (Ruppel, 1979). According to Cotes (1979), the normal range of PEFR value in healthy adult males, depending on their age and size, is from 360 to 900 L/min and in females from 168 to 606 L/min.

7. **Maximal Voluntary Ventilation (MVV)** is the largest volume expired in a minute during the act of voluntary hyperventilation - breathing as deeply and rapidly as possible. The test is conducted for a specific interval, i.e., for 10-, 12- and 15-seconds (Ruppel, 1979). It measures the status of the respiratory muscles, the compliance of the lung thorax system, and the resistance offered by the airways and tissues. The maximal voluntary ventilation in adults, depending on their age and size, is in the range of 47 L/min to 253 L/min in males and 55 L/min to 139 L/min in females (Cotes, 1979).

8. **Minute Ventilation (MV)** is the volume of gas either breathed in or breathed out in one minute. It includes both the alveolar and dead space ventilation and its magnitude depends on the breathing frequency and tidal volume of air. The expired minute volume is usually slightly smaller than the inspired one, but normally this difference is negligible (Ruppel, 1979).

Appendix II (a) Correlation Matrix for control male subjects (n=110)

Age	Sit. height	Stan. height	Weight	FFM	FVC	FEV_1	FEV_1 %	FEF	MMFR	PEFR	MV	MVV
1.00												
-0.18	1.00											
-0.23	0.66	1.00										
0.23	0.33	0.36	1.00									
0.22	0.42	0.43	0.94	1.00								
-0.46	0.51	0.56	0.27	0.36	1.00							
-0.64	0.46	0.50	0.12	0.21	0.91	1.00						
-0.51	-0.03	-0.01	-0.28	-0.29	-0.03	0.39	1.00					
-0.29	0.38	0.25	0.20	0.28	0.45	0.55	0.32	1.00				
-0.55	0.16	0.22	-0.02	-0.01	0.38	0.69	0.81	0.52	1.00			
-0.49	0.22	0.20	0.08	0.11	0.45	0.63	0.52	0.54	0.68	1.00		
0.03	0.07	0.03	0.06	0.02	-0.12	-0.14	-0.06	-0.13	-0.07	-0.15	1.00	
-0.50	0.18	0.12	-0.16	-0.15	0.35	0.54	0.51	0.39	0.53	0.55	-0.11	1.00

Appendix II (b) Correlation Matrix for control female subjects (n = 101)

	Age	Sit. height	Stan. height	Weight	FFM	FVC	FEV_1	FEV_1 %	FEF	MMFR	PEFR	MV	MVV
Age	1.00												
Sit height	-0.22	1.00											
Stan height	-0.07	0.76	1.00										
Weight	0.01	0.48	0.39	1.00									
FFM	0.00	0.51	0.45	0.83	1.00								
FVC	-0.48	0.43	0.44	0.25	0.30	1.00							
FEV_1	-0.52	0.42	0.44	0.19	0.25	0.90	1.00						
FEV_1 %	-0.08	-0.04	-0.05	-0.19	-0.16	-0.24	0.16	1.00					
FEF	-0.03	0.16	0.06	0.05	0.02	0.30	0.38	0.16	1.00				
MMFR	-0.27	0.17	0.13	0.02	0.01	0.26	0.59	0.75	0.49	1.00			
PEFR	-0.17	0.14	0.17	0.13	0.12	0.41	0.51	0.14	0.46	0.48	1.00		
MV	-0.13	0.08	0.02	0.05	0.05	0.05	-0.04	-0.05	0.05	-0.01	0.12	1.00	
MVV	-0.31	0.22	0.20	0.15	0.18	0.47	0.52	0.05	0.22	0.35	0.42	0.17	1.00

R E F E R E N C E S

Abramowitz, S., Leiner, G.C., Lewis, W.A., and Small, M.J. 1965. Vital capacity in the Negro. *Amer. Rev. Respir.Dis*. 92:287.

ACGIH. 1983. *Air Sampling Instruments for Evaluation of Atmospheric Contaminants*. 6th ed. Cincinnati, Ohio. pp. p-6 - p-11.

ACGIH. 1988. *Threshold Limit Values and Biological Exposure Indices for 1988 - 1989*. Cincinnati, Ohio. pp. 16 & 31.

American Thoracic Society. 1962. Chronic bronchitis, Asthma, and Pulmonary Emphysema. *Amer.Rev.Respir. Dis.*, 85:762-768.

Arnott, W.M. 1962. Respiratory Failure. *Lancet*. 1:1-7.

Baldwin, E.DeF., Cournand, A., and Richards, D.W.J.R 1949. Pulmonary Insufficiency: II. A study of 39 cases of pulmonary fibrosis. *Medicine*. 28:1.

Berglund, E., Birath, G., Bjure, J., Grimby, G.,Kjellmer I., Sandqvist, L. and Solderholm, B. 1963. Spirometric Studies in Normal Subjects. I. Forced Expirograms in Subjects Between 7 and 70 years of Age. *Acta. Med. Scand*. 173:189 -191.

Berry, G., Mc Kerrow, C.B., Molyneux, M.K.B., Rossiter, C.E. and Tombleson, J.B.L. 1973. A study of the Acute and Chronic Changes in Ventilatory Capacity of Workers in Lancashire Cotton Mills. *Brit. J. Indstr. Med.* 30:25-36.

Berry, G., Molyneux, M.K.B. and Tombleson, J.B.L. 1974. Relationships Between Dust Level and Byssinosis and Bronchitis in Lancashire Cotton Mills. *Brit. J. Industr. Med*. 31: 18-27.

Blockburn, H., Brozek, J., and Tayler, H.L. 1959. Lung Volume in Smokers and Non-smokers. *Ann. Intern. Med.* 51: 68 - 77.

Bosse, R., Costa, P., Cohen, M. and Podolsky, S. 1975. Age, Smoking Inhalation and Pulmonary Function. *Arch. Environ. Health*. 30: 495 - 498.

Bouhuys, A., Wolfson, R.L., Horner, D.W.,Brain, J.D. and Zuskin, E. 1969. Byssinosis in Cotton Textile Workers: Respiratory Survey of a Mill with Rapid Labour Turnover. *Ann. Intern. Med.* 71 (2): 257-269.

Bouhuys, A. and Zuskin, E. 1976. Chronic Respiratory Diseases in Hemp Workers: a follow-up study. 1967 - 1974. *Ann.Intern. Med*. 84: 398 - 405.

Brooks, S.M. 1982. The Evaluation of Occupational Airways Diseases in the Laboratory and Workplaces. *J. Allergy. Clin. Immunol*. 70 : 56 - 66.

Colin, R.W. and Jesus, T.S. 1971. The Respiratory Effects of Regular Cigarette Smoking in Women. *Amer. Rev. Resp. Dis*. 103(1) : 26 - 37.

Cherniack, R.M. and Raber, M.B. 1972. Normal Standards for Ventilatory Function Using an Automated Wedge Spirometer. *Amer. Rev. Res. Dis*. 106:38 - 46.

Cole, T,J, 1974. The Influence of Height on the Decline in Ventilatory Function. *Int. J. Epidemiol*. 3(2): 145-151.

Cotes, J.E. 1979. *Lung Function: assessment and application in medicine*. 4th ed. Blackwell Sc. Pub. Oxford. pp. 18-91.

Cotes, J.E. 1983. Lung Function Tests. *Enclopaedia of Occupational Health and Safety*. 3rd ed. Vol. 2 (L-z). p. 1250.

Da Costa, J.L. 1971. Pulmonary Function Studies in Healthy Chinese Adults in Singapore. *Amer. Rev. Respir. Dis.* 104: 128-131.

Durnin, J.V.G.A. and Womersley, J. 1974, Body Fat Assessed from Total Body Density and its Estimation from skinfold Thickness : measurements on 481 men and women aged from 16 to 72 years. *Brit. J. Nutrition*. 32(1) 77 - 97.

Edward, A.E, 1984. The Skin Occupational Diseases. *Arch. Environ. Health*. 39(3): 144 - 149.

Femi-Pearse, D. and Elebute, E.A. 1971. Ventilatory Function in Healthy Adult Nigerians. *Clin. Sci.* 41:203 - 211.

Flint, F.J. and Kahan, M.O. 1962. Clinical use of Peak Flow Meter. *Brit. Med. J.* 2 : 1231 - 1232.

Fox, A.J., Tombleson, J.B.L., Watt, A. and Wilkie, A.G. 1973. A Survey of Respiratory Disease in Cotton Operatives. Part II. Symptoms, dust estimates, and the effect of smoking habit. *Brit. J.Industr. Med.* 30:48-53.

Frost, J. and George, J. 1953. The Clinical Evaluation of Disability in Silicosis. *Acta. Med. Scand.* 147 : 349.

Gaensler, E.A. and Wright, G.W. 1966. Evaluation of Respiratory Impairment. *Arch. Environ. Health*. 12 :146-148.

Gandevia, B., and Hugh-Jones, P. 1957. Terminology for Measurements of of Ventilatory Capacity. A report to the Thoracic Society. *Throx*. 12:290 - 293.

Gandevia, B., and Milne, J. 1965. Ventilatory Capacity Changes on Exposure to Cotton Dust and their Relevance to Byssinosis in Australia, *Brit. J. Industr. Med.* 22: 295.

Gilson, J.C., Scott, H., Hopwood, B.E.C., Roach, S.A., Mc Kerrow, C.B. and Schilling, R.S.F. 1962. Byssinosis: The Acute Effect on Ventilatory Capacity of Dusts in Cotton Ginneries, Cotton, Sisal, and Jute Mills. *Brit. J. Industr Med.* 18:9.

Hale, L.W., and Sheers, G. 1963. Silicosis in West Country Granite Workers. *Brit. J. Industr. Med.* 20:218.

Haubulein, H.G., Rebohle, E., Beck, B. 1983. Dust, biological effects of. *Encyclopaedia of Occupational Health and Safety*. ILO. Geneva. Vol. 1 (A-K). pp. 680-684.

Heller, R.F., Hayward, D.M. and Farebrother, M.T.B. 1986. Lung Function of Farmers in England and Wales. *Thorax*. 41:117-121.

Higgins, I.T.T. 1957. Respiratory Symptoms, Bronchitis, and Ventilatory Capacity in Randam Sample of an Agricultural Population. *Brit. Med. J.* 2:1198-1203.

Hurtado, A., Kaltreider, N.L., Fray, W.W., Brook, W.D.W., and Mc Cann, W.S., 1935. Studies of Total pulmonary Capacity and its Subdivisions. VIII. Observation on cases of pulmonary fibrosis. *J. Clin. Investigation*. 14:81.

ILO. 1965. *Guide to the Prevention and Suppression of Dust in Minning, Tunnelling and Quarrying*. Geneva. p.301.

Irwing, L.M. and Rocks, P. 1978. Lung Function and Respiratory Symptoms in Silicotic and Non-silicotic Gold Miners. *Amer. Rev. Respir. Dis.* 117 (3): 429-437.

Jain, B.L. and Patrick, J.M. 1981. Ventilatory Functoin in Nigerian Coal Miners. *Brit. J. Industr. Med.*38:275-280.

Kalacic, I. 1973. Ventilatory Lung Function in Cement Workers. *Arch. Environ. Helth.* 26: 84-85.

Kalacic, I. 1973. Chronic Nonspecific Lung Disease in Cement Workers. *Arch. Environ. Helth.* 26: 78-83.

Kaltreider, N.L. and Mc Cann, W.S. 1937. Respiratory Response During Exercise in Pulmonary Fibrosis and Emphysema. *J. Clin. Invest.* 16: 23.

Kamat, S.R., Thiruvengadam, R.V. and Rao, T.L. 1967. A Study of pulmonary Function Among Indians and Assessment of the Wright Peak Flow Meter in Relation to Spirometry for field Use. *Amer. Rev. Respir. Dis.* 96: 707-716.

Keith, W. and Morgan, C. 1979. Clinical Significance of Pulmonary Function Tests. Disability or Disinclination? Impairment or Importuning ? *Chest.* 75 (6): 712-715.

Khogali, M. 1969. A Population Study in Cotton Ginnery Workers in the Sudan. *Brit. J. Ind. Med.* 26: 308-313.

Kleinfeld, M., Messite, J., Shapiro, J., and Swencicki, R. 1965. Effect of Talc Dust Inhalation on Lung Function. *Arch. Environ. Health.* 10 (3): 431-437.

Kondakis, X.G. and Pournaras, N. 1965. Byssinosis in Cotton Ginneries in Greece. *Brit. J. Industr. Med.* 22: 291.

Kory, R.C., Callahan, R., Boren, H.G. and Syner, M.J.C. 1961. The Veterans Administration-Army Cooperative Study of Pulmonary Functon. *Amer. J. Med.* 30: 243-258.

Lambert, P.M., and Reid, D.D. 1970. Smoking, Air Polution and Bronchitis in Britain. *Lancet.* 1: 853-857.

Leuallen, E.C. and Fowler, W.S. 1955. Maximal Midexpiratory Flow. *Amer. Rev. Tub. Pul. Dis.* 72: 783-800.

Lloyd, M.H., Gauld, S., Copland, L. and Soutar, C.A. 1984. Epidemiological Study of the Lung Function of Workers at a Factory Manufacturing polyvinaylchloride. *Brit. J. Indstr. Med.* 41: 328-333.

Malik, M.A., E. and Lee, W.R. 1972. Prediction Values for the Ventilatory Capacity in Male West Pakistani Workers in the United Kingdom. *Thorax.* 27: 611-619.

Mc Donald, J.C., Becklake, M.R., Gibbs, G.W., Mc. Donald, A.D. and Rossiter, C.E. 1974. The Health of Chrysotile Mine and Mill Workers in Quebec. *Arch. Environ. Health.* 28: 61-68.

Mengesha, Y.A. and Mekonnen, Y. 1985. Spirometric Lung Functon Tests in Normal Nonsmoking Ethiopian Men and Women. *Thorax.* 40: 465-468.

Merchant, J.A., Halprin, G.M., Hudson, A.R., Kilburn, K.H., Mc Kenzie, W.M., Bermanzohn, P. Hurst, D.J., Hamilton, J.D. and Germino, V.H. 1974. Evaluation Before and After Exposure - The pattern of physiological Response to Cotton Dust. *Ann. N.Y. Acad. Sci.* 221: 38-43.

Miller, G.J., Ashcroft, M.T., Swan, A.V. and Beadnell, H.M.S.G. 1970. Ethnic Variaton in FEV_1 and FVC of African and Indian Adults in Guyana. *Amer. Rev. Resp. Dis.* 102: 979-981.

Miller, G.J., Cotes. J.E., Hall, A.M., Salvosa. C.B. and Ashworth, A. 1972. Lung Function and Exercise Performance of Healthy Carribbean Men and Women of African Ethnic Origin. *Q. J. Exp. Physiol.* 57: 325-341.

Tinker, C.M. 1961. Peak Expiratory Flow Measured by Wright peak Flow Meter. Distribution of Values in Men Aged 30-59 Who Denied Respiratory Symptoms. *Brit. Med. J.* 1: 1365-1366.

Valic, F., Zusin, E., Walford, J. Kersic, W., and Paukovic, R. 1968. Byssinosis, Chronic Bronchitis, and Ventilatory Capacities in Workers Exposed to Soft Hemp Dust. *Brit. J. Industr. Med.* 25: 176.

Valic, F. and Zuskin, W. 1972 (a). Byssinosis: A Follow-up Study of Workers Exposed to Fine Grade Cotton Dust. *Thorax*. 27: 479-463.

Valic, F. and Zuskin, E. 1972 (b). Effects of different Vegetable Dust Exposure. *Brit. J. Ind. Med.* 29: 293-297.

Valic, F. Beritic, D. and Butkoic, D. 1976. Respiratory Response to Tobacco Dust Exposure. *Amer. Rev. Respir. Dis.* 113 (6): 751-755.

Valic, F. and Zuskin, E. 1977. Respiratory functon Change in Textile Workers Exposed to Synthetic Fibers. *Arch. Env. Health*. 32 (6): 383-387.

Vedal, S., Chan-Yeng, M., Endarson, D., Fera, T., Maclean, L., Kam, S. Tse, Langille, R. 1986. Symptoms and Pulmonary Function in Western Red cedar Workers Related to Duration of Employment and Dust exposure. *Arch. Environ. Health*. 41 (3): 179-184.

Viallat, J.R., Boutin, C., Pietri, J.F., and Fondarai, J. 1983. Late progression of Radiographic Changes in Canari Chrysotile Mine and Mill Workers. *Arch. Environ. Health*. 38(1): 54-58.

Warell, D.A., Harrison, B.D.W., Fawcett, I.W., Mohammed, Y.M Mohammed, W.S., Helen, M.P. and Barbara, J.W. 1975. Silicosis Among Grindstone Cutters in the North of Nigeria. *Thorax*. 30(4):389-398.

Weill, H., Jones, R. 1975. The Chest Roentgenogram as an Epidemiologic Tool. *Arch. Environ. Health*. 30: 435-439.

West, J.B. 1979. *Respiratory Physiology*. 2nd.ed. Williams & Wilkins. Baltimore/London. pp. 143-146.

Whitfield, A.G.W., Arnott, W.M., and Waterhouse, J.A.H. 1951. The Effect of Tobacco Lung Volume. *Quart. J. Med*. 20: 141- 147.

WHO. 1983. *Recommended Health-based Occupational Exposure Limits for Selected Vegetables*. Report of a WHO Study group. Technical Report Series. No. 684. pp. 17 & 52.

WHO. 1984. *Evaluation of Exposure to Airborne particles in the Work Environment*. WHO offset publications. No. 80. pp.17,53 & 84.

Zuskin, E. and Valic, F. 1972. Respiratory Symptoms and Ventilatory Functon Changes in Relaton to Length of Exposure to Cotton Dust. *Thorax*. 27: 454-458.

Zuskin, E., Volic, F. and Bonhuys, A. 1976. Byssinosis and Airway Responses due to Exposure to Textile Dust. *Lung*. 154: 17-24.