

**SPIROMETRIC AND GAS TRANSFER MEASUREMENTS AMONG NORMAL
ADULT SOUTH AFRICAN MEN: AN INVESTIGATION INTO ANTHROPOMETRIC,
SOCIO-ECONOMIC, RACIAL AND ENVIRONMENTAL FACTORS INFLUENCING
LUNG FUNCTION**

by

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This thesis is submitted to the Faculty of Medicine, University of Cape Town, in fulfillment of the requirements for the degree of Doctor of Philosophy (Medicine).

I, Jonathan Gerald Goldin, hereby declare that the work on which this thesis is based is original (except where acknowledgements indicate otherwise) and that neither the whole work, nor any part of it, has been, is being, or is to be submitted for another degree in this or any other University.

Signed

JONATHAN GERALD GOLDIN

January, 1989

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This thesis is dedicated firstly to my family for their devoted support, boundless love and warm affection and, secondly, to the real researchers of this world who participate in projects in many varied roles without the due recognition they deserve.

INTRODUCTION

Spirometric and Gas Transfer Measurements among normal adult South African men

An investigation into anthropometric, socio-economic, racial and environmental factors influencing lung function.

In modern clinical practice the data derived from pulmonary function tests are an integral part of the evaluation of pulmonary disease states. Such data may shed light on the nature of the disease state, the extent (severity) of the disease and the degree of functional impairment that is present. It is generally recognised that there is a lack of consistent data regarding "normal" values in pulmonary function. Despite great progress in standardising instrumentation, methodology and calculation of the lung function test, the interpretation of the test is complicated by the lack of standardised prediction values. The identification of race as a confounding variable is particularly important in an evaluation of appropriateness of currently used pulmonary function reference values. It has been pointed out that reference values for blacks, in particular, have deficiencies and that this issue demands urgent investigation. The study of differences in lung function in different race groups is complex. Race, itself, is a controversial concept and its close relationship to social stratification needs to be explored before differences may be attributed to race itself.

OBJECTIVES

The objective of this investigation was to examine the relative influences that socio-economic and environmental factors race and anthropometric factors have on the lung function measurements of adults. A second objective was to collect data regarding the spirometry of normal South African whites and blacks based on an urban-living population not exposed to an adverse respiratory environment.

AIMS

The aims of the investigation were to:

- (a) Identify social stratification indicators that may be used to identify sub-groups within a population and to determine the influence these indicators have on lung function;

- (b) to determine which anthropometric measurements influence lung function and to examine their relationship with social stratification influences;
- (c) to test the hypothesis that socio-economic and environmental influences during childhood play a dominant role in the causation of lower spirometric (FVC, FEV₁) values that have been repeatedly demonstrated in blacks (compared to whites);
- (d) to gather (FVC and FEV₁) data and single breath gas transfer factor (TLCO_{SB}) measurements in normal non-dust exposed adult blacks and a comparable groups of whites;
- (e) to develop, by means of accepted methods of statistical modelling, prediction equations for spirometry (FVC, FEV₁) and single breath gas transfer (TLCO_{SB}) of normal adult black and white South African males.

METHODS

Study Population

The definition of the study population was: All male employees of the First National Bank's administrative offices in central Johannesburg. The definition was extended to include all black employees who held clerical or more senior jobs throughout the branches in the Johannesburg area and also to include senior black male administration staff working for the South African Breweries. Race was defined according to skin colour for the purposes of this investigation.

Data Collection

Data was collected by trained lay interviewers using an adapted ATS questionnaire with respect to:

1. identification data of each subject;
2. social stratification histories; pertaining to both childhood and current adulthood status;
3. cardio-respiratory symptoms and previous cardio-respiratory pathology;
4. smoking status;
5. lung physiology tests were performed using both equipment (Morgan Transfer Test Autolink and Vitalograph^R Spirometer) and methodology that adhered to the latest American Thoracic Society (ATS) and Intermountain Thoracic Society (ITS) standards;
6. chest radiographs (full-size, posterior, anterior and lateral radiographs using a standardised technique).

Quality control routines were designed to check the validity of data collected in each of these areas.

Data Analysis

Data analysis was accomplished using an IBM computer using the SAS. Descriptive statistics and frequency tables are presented for all subjects who entered the trial as well as for the normal subgroup. Descriptive statistics consist of means and standard deviations where data is normally distributed and medians is not normally distributed. Social stratification indicators were selected a priori and their relationship explored by using the Kappa statistic. Comparison of sub-groups with respect to categorical variables was done using Chi-squared or Fisher's exact test where Chi-squared was not appropriate because of small frequencies. Comparison of sub-groups with respect to continuous variables was done using t-tests or median tests where the data was not normally distributed.

The data of each subject was screened to identify "normal cases". Multiple linear regression equations for FEV₁, FVC, TLC_{DSB} were obtained using anthropometric data, social stratification indicators, including race, as independent variables. The Mallow's CP statistic which estimates the mean square error of prediction of a given equation was used to identify the best equation. Lung function values were compared between different social stratification groups using an analysis of covariance.

RESULTS

Response Rates

1025 (611 black and 414 white) men were made available to this study. 510 (82%) black and 286 (69.1%) white participated in the survey.

Social Stratification Analysis

Kappa interrator analysis allowed the identification of father's occupation, school education, place of birth and "race" as the "best indicators" of childhood social stratification. The "best indicators" of adulthood (current) social stratification were current income, occupation, home ownership, "race" and a composite indicator ADEC. This analysis also demonstrated:

1. that within the study population the best indicator of social stratification was "skin colour";
2. that the black group is inferior to the white group with respect to every indicator of social stratification indicator and
3. within the black population a very slight social stratification gradient exists.

Lung Function Tests

767 (94.4%) participants attempted flow volume loops (Autolink) and 729 (91.6%) spirometry (Vitalograph). 702 (88.2%) attempted both Autolink and Vitalograph testing, 722 (90.7%) flow volume

loops and 643 (97.1%) spirograms met ATS and ITS standards for acceptability and reproducibility. Comparison of the spirometric measurements obtained demonstrated consistently higher measurements (160 ml mean for FVC and 211 ml mean for FEV₁) ($p = 0.001$). It was therefore decided to perform separate analyses on data obtained from the different pieces of equipment.

Anthropometric Population Data

The mean age of the study population was 40.1 years (standard deviation 10.53), with a range of 20 - 72 years. The mean age for the two "race" groups were similar, 39.8 (blacks) and 40.6 (whites) (t-test $p = 0.91$). The average age of the urban born (mean 38.1, standard deviation ± 8.69) and the high "social stratification group" defined by father's occupation (36.04 ± 8.103) were the lowest, while the mean ages of the "black rural" (42.87 years ± 9.23) and "black low" group (41.3 years ± 9.8) are the highest. The sitting height of the white group was 91.7 cm, standard deviation 3.62, and was significantly higher than the black group (86.207 ± 3.258) in (t-test; $p = 0.001$) there was no significant difference. There is no difference in height within the black group when divided either by place of birth or by social class (as defined by father's occupation). The same is true for standing height which is higher for the white group (178.8 cm ± 6.8 cm) than the black group (169.7 cm ± 6.0 cm) (t-test; $p = 0.001$). The mean sitting height/standing height ratio for the study population is 0.51 ± 0.1 . There is no differences in the mean sitting/standing height ratio for the black (0.507 ± 0.0013) or white (0.513 ± 0.0013) groups (t-test; $p = 0.746$). There is no difference in this ratio when the groups are divided by either place of birth or father's occupation.

Normal Population

The determinants of lung function were analysed using data obtained from the 208 "healthy" individuals, 128 of whom were black and 80 white. 195 (38.2%) blacks and 94 (32.9%) whites were excluded on the basis of their smoking histories only. Other than this criteria, the most frequent reason for exclusion (7.5% of blacks and 10.5% of whites) was the combination of smoking and a respiratory symptom. The radiograph survey resulted in 9 blacks (1.8%) and 7 whites (2.4%) being excluded on the basis of the abnormal radiograph alone. The age distribution of the "healthy" population was similar to that of the total study population, 39.6 years ± 10.8 . The various other anthropometric measurements in this group were also not significantly different to that of the total study population, nor was there any difference within the various sub-groups.

Regression Analysis

The best subsets of variables predicting the various lung functions are presented below (only the Autolink analysis is presented in the abstract):

FVC (All healthy) n = 165 (race in)

0.123 sit ht - 0.028 age - 12.57 height ratio + 0.589 race + 0.409

(R² = 0.73 CP 2.07)

FVC (All healthy) n = 165 (race out)

0.169 sit ht - 0.028 age - 13.52 height ratio - 0.207 ADEC - 1.51

(R² = 0.68 CP 3.10)

FVC (White) n = 71

0.123 sit ht - 0.028 age - 13.35 height ratio + 0.567 ADEC - 1.38

(R² = 0.62 CP 5.59)

FVC (Black) n = 93

0.141 sit ht - 0.018 age - 13.70 height ratio - 0.009 wt + 0.288

(R² = 0.39 CP 4.28)

FEV₁ (All healthy) n = 180 (race in)

0.092 sit ht - 0.034 age - 9.537 height ratio + 0.485 race - 0.127 born + 1.664

(R² = 0.69 CP 2.15)

FEV₁ (All healthy) n = 180 (race out)

0.113 sit ht - 0.036 age - 9.535 height ratio - 0.266 ADEC + 0.668

(R² = 0.66 CP 3.37)

FEV₁ (White) n = 71

0.043 stand ht ht - 0.038 age - 0.366 born - 1.243

(R² = 0.58 CP 5.09)

FEV₁ (Black) n = 86

0.036 stand ht - 0.032 age - 1.18

(R² = 0.55 CP 1.012)

Analysis of covariance demonstrated significantly higher values for FVC and FEV₁ for whites, compared to that of blacks, irrespective of stratification indicator used. No significant difference was demonstrated for lung functions within the black group stratified by social stratification parameters.

TLCOS_B

TLCO_{SB} measurements were made in 436 (54.75%) of subjects. 424 functions met both ATS and ITS standards. 100 were included in the final regression analysis. The best subsets were as follows:

$$0.439 \text{ stand ht} - 3.05 \text{ age} + 2.88 \text{ race} + 23.38$$

$$(R^2 = 0.55 \text{ CP } 1.30)$$

$$1.08 \text{ sit ht} - 0.32 \text{ age} - 102.8 \text{ ht ratio} + 11.49$$

$$(R^2 = 0.55 \text{ CP } 1.67)$$

Analysis of covariance for adjusted TLCO_{SB} demonstrated a significant difference between the two race groups (t-test; $p = 0.048$) when corrected for standing height and age. However, when adjusted using the best independent variables identified in the regression analysis sitting height and height ratio, no significant difference was demonstrated between the two race groups (t-test; $p = 0.23$). Comparison of TLCO_{SB} between different social stratification groups shows no significant difference between these groups. When current income is used as a stratification indicator

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INTRODUCTION

In modern clinical practice, the data derived from pulmonary function tests are an integral part of the evaluation of pulmonary disease states. Such data may shed light on the nature of the disease state, the extent (severity) of the disease and the degree of functional impairment that is present. It is generally recognised that the published reference values for black South Africans have deficiencies and that this issue demands urgent investigation (1-6).

Given the observed differences of pulmonary function tests between races, we postulated that these differences are due to socio-economic influences rather than genetic factors.

The following sections will:-

- a) review the history of pulmonary function testing, the difficulties experienced in studying lung function, and those series which have given rise to the data that are used by clinical laboratories as normal predicted values;
- b) review, specifically, the studies in which pulmonary function tests of different "race" groups have been compared and show that in most of these studies socio-economic stratification had not been taken adequately into account;
- c) review the concept of "race" with particular reference to its definition and relationship to social stratification;
- d) review the literature and highlight the difficulties encountered in adopting different systems of social stratification in (i) any society undergoing rapid urbanization and industrialization; (ii) the socio-political problems peculiar to the Republic of South Africa and (iii) any society with wide cultural differences;
- e) review the literature with regard to the mechanisms whereby populations of lower socio-economic status might be exposed to influences that reduce pulmonary function tests;

Introduction

- f) review the few studies in which socio-economic factors have been taken into account and show that some stratification reduced inter-ethnic differences of lung function tests;
- g) describe in outline the design of a study which may demonstrate the relative contribution of ethnicity and socio-economic status to the observed differences in pulmonary function tests among whites and blacks.

CHAPTER 1

1. THE DEVELOPMENT OF LUNG FUNCTION TESTING FROM ITS INCEPTION TO THE CURRENT STATE OF THE ART

This chapter is presented in order to highlight the many problems inherent in understanding normal lung function and its determinants. The complexity of this task explains the background for the need for a study to examine the inter-relationship between two less well understood, but obvious, influences on lung function, viz race and socio-economic factors.

1.1 HISTORICAL REVIEW OF LUNG FUNCTION TESTING

1.1.1 The history of spirometry

(a) Introduction

One hundred and forty years ago (in 1846), John Hutchinson devised a water-sealed, counterweighted spirometer and described and defined the vital capacity in his paper entitled "On capacity of the lungs and on respiratory function with a view of establishing a precise and easy method of detecting disease by spirometer"⁷. In his classic series, vital capacity measurements were measured in more than three thousand subjects, taking the largest of at least three efforts. This pioneer study, which remains one of the largest single series reported, demonstrated the importance of age and anthropometric differences in lung function and the ability to interpret lung functions by comparing them to values derived from a "normal" population. He established that vital capacity is directly related to height, inversely proportional to age in the 36-65 year age range and reduced by diseases such as tuberculosis and cardiac failure.⁸ His classic analysis concludes with this statement "...weight can never be the sure guide that height is, because the former varies at any time in life, even in a few days, whereas the latter varies only at extremes of life".⁷

Spriggs⁸, in his excellent review of the history of spirometry, points out that Hutchinson's spirometer had been evolved from simpler devices. The first recorded measurement of a vital capacity was that performed by James Jurin on himself by blowing air into a bladder in 1718. In 1749 a water displacement spirometer was invented by Daniel Bernouilli and this was followed by Edward Kentish's "pulmometer" devised in 1813 and composed of a graduated bell jar inverted in a water bath. Spriggs points out that it was in fact Kentish who first measured the VC in health and disease and made the first reference to a predicted value: "Mr S, aged 17, phtysis; by the pulmometer he could only inhale 1140 cc of air. From his stature he ought, if his lungs had been sound, to have inhaled 4,000 cc".⁸

Although not the first, John Hutchinson is generally regarded as the father of spirometry. The simplicity and rapidity with which vital capacity could be measured following his development of a water-sealed spirometer, led to an abundance of subsequent studies with the purpose of quantitating normal lung function and its determinants. Initial developments saw a graphic recording system being added to spirometers in 1879 and the development of sophisticated closed-circuit instruments being devised by Tissot in 1904, Bohr in 1907 and Krogh in 1916.

(b) Early Studies Relating Anthropometric Factors to Lung Function

The first half of the twentieth century saw a rash of studies aimed at elucidating the various determinants of lung function and were related to sex and standing height. Peabody and Wentworth in 1917 related vital capacity to body surface area and were the first to present normal values related to sex and standing height⁹. Lundsgaard and Van Syke demonstrated a relationship between body surface area and thoracic volume¹⁰. West related the vital capacity to both body surface area and prepared the first set of practical prediction formulae¹¹. Hewlitt and Jackson reviewed West's data and modified it slightly following their study of vital capacity measurements in a group of college students published in the same year¹². Myers related vital capacity to body weight, body surface area and to sitting height and established tables of normal standards based upon these relationships¹³. Kaltreider et al, in 1938 confirmed Hutchinson's demonstration of the effect of age on lung function¹⁴. A milestone in the field of

pulmonary function testing is generally accepted to be the extensive research postulates of Cournand and Richards in 1914, which culminated in the classic report of Baldwin, Cournand and Richards in 1948. They attempted to classify the physiological aspects of lung function, the clinical methods of analysis and presented standard values for normal subjects. The report served as a handbook for workers in the field for a great portion of the middle of the century^{15,16}.

(c) Early Sophisticated Testing Techniques and Larger Scale Studies

In 1948 Tiffeneau and Pinelli (as reviewed by Spriggs)⁸ and three years later Gaensler¹⁷, demonstrated the usefulness of the time volume relations, including the one-second forced expiratory volume (or FEV₁) in the performance of vital capacity. During the late 50's, work showed the importance of measurements of expiratory flow rates¹⁸. In 1955 Leuallen and Fowler¹⁹ defined the maximum mid-expiratory flow (MMF or FEF 25 to 75%). Dayman²⁰ meticulously constructed tangents from the spirogram in an attempt to calculate instantaneous flows at various volumes during the FVC manoeuvre. Consequent upon this rapid development, the first of the very large lung function studies was heralded by the 1961 Veterans Administration Cooperative Study of pulmonary function whose results were used, and indeed are still being used, in many centres²¹.

(d) The Modern Era

In 1962, Bartlett and Phillips used a wedge spirometer and potentiometer to record what they described as "the velocity volume loop", using an oscilloscope²². They suggested that this would be a composite test which would allow an assessment of several components of pulmonary function. The advent of pneumotachygraphs, spirometers with electrical outputs and rapidly responding mechanical XY recorders brought maximum expiratory flow volume curves into universal use in clinical laboratories. Computerisation of pulmonary function systems has further increased the amount of data derived from the forced expiratory manoeuvre and simplified the accessing of information obtained. However, these advances have opened up new sources of potential error.

1.1.2 Historical development of the single breath diffusing capacity test (D_LCO_{SB} ; synonyms: $TLCO_{SB}$, transfer test)

Comroe²³ recently reviewed the development of the transfer test. The test was devised by Marie Krogh in order to disprove the then popularly held concept that gas exchange in the lungs takes place through both diffusion and a process of active secretion. Krogh²⁴, in her paper published in 1915, described her original technique which required the subject to inspire a 1% CO mixture from residual volume (RV), immediately clear his deadspace (in order to provide the initial alveolar CO), hold his breath for six seconds and then complete his expiration (to provide the final alveolar CO). Although she made measurements in both normal subjects and patients with various respiratory disorders, she did not popularize the test for clinical use. In 1946, Lilienthal, Riley et al developed an ingenious but tedious method for estimating DL. The test involved multiple trial and error attempts using two levels of oxygen and a cumbersome technique for measuring arterial PO_2 ²⁵.

Comroe credits Kety (in 1950) with the interest in the revival of Krogh's single breath carbon monoxide methods which had been totally neglected since Krogh's work in 1915 and the suggestion that it should be used as a clinical test. During the late 1950's the chemical reaction of CO with haemoglobin was worked out^{26,27}. The addition of helium simplified the test considerably, since it allowed the initial alveolar concentration of CO to be estimated without the more complicated respiratory manoeuvres required by Krogh's technique^{27,28}. The test was further greatly simplified by utilising the single breath dilutional alveolar volume in the calculation of D_LCO_{SB} in place of the RV separately measured by multiple breath dilution or plethysmography. Ogilvie et al are credited with having described the modern technique for measurement of the single breath carbon monoxide diffusing capacity of the lung²⁸. The test has subsequently been used to assess patients with suspected lung disease and in epidemiological surveys. The test also allows a measurement of alveolar volume (VA), so that the specific diffusing capacity per litre lung volume may be derived (DL/VA). This latter expression is a mathematical equivalent of Krogh's diffusing constant²⁹. A 3-equation method has recently been developed for

measuring TLC_{SB} which may have advantages over current methods, although this is yet to be validated and is not in general use³⁰.

In South Africa the European convention of using the term transfer factor (T_L), instead of D_L , is used. T_L is preferred because the measurement is influenced by several factors such as haemoglobin (Hb) concentration and reaction rate of gas with Hb in addition to the diffusing characteristics of the lung. This convention will be adhered to in this publication.

1.1.3 The history of total lung capacity (TLC) determinations

The relatively simple methods available for the measurement of vital capacity have been described in Section 1.1.1. To derive TLC, the more elusive residual volume compartment of the lung needs to be measured. Several methods for measuring the residual volume have been established. Brown, in his review of the subject credits Humphrey Davy (in 1800) with the first documented measurement of static lung volumes using hydrogen and a method akin to the closed circuit dilutional method in common use today³¹. Helium, an inert and less dangerous gas, was substituted for Hydrogen with the advent of the thermal conductivity meter³².

A second method involving the washout of Nitrogen appeared in 1918¹⁰: Cournand and Richards perfected this technique with the development of the open-circuit technique³³. A third method, based on Boyle's law, utilising the body plethysmograph was perfected by Dubois et al in 1956³⁴. The fourth method for calculating TLC is from the chest radiograph: two methods are in current use. The first uses a planimetric measurement of thoracic area from a postero-anterior chest radiograph combined with a measured thoracic diameter from a lateral view³⁵. The second involves representing the lungs as sums of ellipsoidal volume using both PA and lateral chest radiograph³⁶.

1.2 LUNG FUNCTION TESTING: THE CURRENT STATE OF THE ART

1.2.1 Spirometric (FVC and FEV₁) normal value determination

(a) Introduction

The development of more sophisticated apparatus and techniques for measuring pulmonary function has resulted in many attempts to study and define normal lung mechanics and function. The profusion of lung function studies has resulted in an almost equal number of normal standards and formulae for prediction being proposed. A single test of lung function that is both a highly sensitive and specific measure of early lung disease has not been identified, despite intensive investigations to this end. In an evaluation, published in 1984, of the clinical significance of pulmonary function tests, Detels et al (in a population based study of 1201 patients between 25-50 years) concluded that spirometry and flow volume curves showed a high concordance of abnormality with a relatively small degree of discordance with each other and with the FEV₁/FVC ratio. This work clearly demonstrates that there is a place for spirometry in clinical practice, but that the major problem in its use revolves around the establishment of normal values³⁷. Spirometric measurements are popular because they provide information on two basic pathophysiologic processes affecting the mechanical properties of the respiratory apparatus, airflow limitation and restriction of lung volumes. Recently, automated instruments which derive various measurements of flow, as well as volumes from the flow volume curve have become more widely used. The flow volume curve yields more information than the spirogram by permitting easier recognition of abnormalities predominantly located in the large or small airways^{38,39}. Difficulties, however, exist with the interpretation of small airways function because of the wide variation that is demonstrated for normal individuals.

The transfer factor for carbon monoxide provides information on the gas exchange function of lungs. The role of this test in assessing lung function in both epidemiological and occupational lung disease evaluations has been well reviewed by Make⁴⁰. At the clinical level the transfer test may be a more sensitive indicator of early parenchymal disease than spirometry. The technical and physiological factors influencing the test make the prediction of normal standards and its use in screening difficult.

Measurements of total lung capacity are not sensitive indicators of lung pathology. The role of this test has been assessed by Miller⁴¹. They are most sensitive for detecting gas trapping and are useful to confirm and evaluate the severity of the findings of obstruction on spirometry. They are also useful to detect restriction, a low TLC is always due to restriction if technically valid (whereas a low FVC may be due to gas trapping) and thus useful to distinguish restrictive from obstructive and combined impairments. The use of these measurements is limited by the many poorly reproducible prediction equations which are derived from small series using different methods.

(b) The Dilemma of Normal Predictive Values

In reviewing the literature it is obvious that pulmonary physiologists, clinicians and epidemiologists all recognise the lack of consistent data regarding "normals" in pulmonary function. In almost every decade, since 1950, prominent physiologists of the time have highlighted the tremendous confusion that abounds. In 1955 Gaensler^{42,43} stated "a great need exists for the uninspiring task of obtaining statistically significant normal values for clinical ventilatory tests". Leinner and associates⁴⁴ in 1969 again pointed out that "there is need for standardisation of methods, prediction formulas and normal ranges for various pulmonary function tests". The epidemiology standardisation project, culminating in the Snowbird Workshop held in 1977, led to the American Thoracic Society (ATS) statement on the standardisation of spirometry, published in 1978, which set standards for lung function measurements in an attempt to eliminate variations due to instrumentation and methodology^{45,46}. Following this statement, much experience has been gained in the use of these recommendations which have been widely endorsed^{47,48,49}. As recently as 1986, Miller pointed out that, although this work made great progress in standardising instrumentation, methodology and calculation of the test (or what he termed "the hardware"), the resulting values were meaningful only by being compared with "predicted values" for normal subjects and in this sphere ("the software") there had been little standardisation.

Despite the tremendous improvement of standardisation of instrumentation, the latest ATS statement emphasises the findings of a recent study in which commercially available spirometers, were compared

and found some instruments with FVC errors as large as 1,5 l, a 25% measurement variation. Only 27 of 53(51%) of spirometers tested met the current rigorous ATS recommendations. Poorly written computer software was one of the major reasons for device failure⁵¹.

In October 1987, the American Thoracic Society published an update (on their 1978 statement) of the current status of the standardisation of spirometry⁵¹. This revision apparently became necessary because of rapid developments in computer controlled spirometric apparatus. It is highly probable that updates of standardisation procedures will again become necessary in the future. Two major agencies, the Intermountain Thoracic Society⁵² and the American Thoracic Society⁵¹, have all recently published their findings that emphasize the controversy associated with selected reference values. These statements also highlight the importance of standardization of methodology. There are at present more than 20 reference value equations for spirometry in common use in the UK, USA and RSA. Their applicability to general populations is seldom clear; most of these reference values do not address questions of the impact of ethnicity on lung function. The dilemma of normal prediction values is worsened by lack of standardization of the interpretive procedures⁵⁰. Different laboratories use different criteria for identifying the best function performed by a patient and/or classifying the result as being within the normal range for the patient. It is not clear how an individual's value should be compared with his or her predicted value. In Britain and South Africa the convention of expressing the result as a percentage of the subject's predicted value (% predicted) has been widely adopted⁵³. In America the American Thoracic Society has recommended that the % predicted should be used as an indication of the degree of deviation from the predicted value and that the 95% confidence level should be used to determine whether an individual's test is to be classified abnormal. A recent editorial has suggested the use of the standardised residuals (SR), which are calculated by dividing the absolute residual by the residual standard deviation (RSD) taken from the regression equation used⁵⁵. The current situation allows so much interpretive variability to result that the same patient may be classified differently in different laboratories⁵⁶.

Clinicians and epidemiologists thus face the dilemma: whether to select a given set of published prediction equations from the large number available or to perform a survey on their local population to establish yet another set which may be locally more appropriate. Clearly the dilemma may only be resolved once equations are published that take into account factors (which may be ethnic or socio-economic) that eliminate the discrepancies between populations. Because of the wide variety of factors influencing lung function, such ideal equations may never be defined.

(c) The Role of Prediction Equations and Reference Values and Overview of their Determinants

Reference values provide the quantitation of the expected (predicted) lung function for a given individual so that assessment of measured (actual) function can be made. In order to assess whether differences in lung function are due to disease or to the effects of physiological factors (e.g. age, height) one requires prediction values that incorporate the effects of these variables⁵⁷. Reference values also allow standards to be set for the reproducibility of results, calibration and functioning of apparatus. These reference standards are often referred to as "normal values". These values are usually derived from lung function surveys. The data collected and analysed from such studies give rise to prediction equations which are used to generate "normal" values. The concept "normal values" is important in order to define "normal" lung function. The concept of "normal" will be discussed in section 1.2.1 (e).

Prediction equations are usually based on regression equations. The latter result from a statistical technique which relates the mean value of a dependent variable to the independent variable. In the case of lung functions the pulmonary function (FVC, FEV₁, TLCO, TLC) is the dependent variable. The independent variables include height, age and sex in most cases, but may include race, weight, other anthropometric measurements, haemoglobin concentration and smoking amongst other less frequently used indices (e.g. environmental exposure)⁵⁸. It is generally accepted that the decision to include an independent variable in the regression equation depends on its statistical significance "P" value and its co-efficient of determination or multiple correlation coefficient (its practical usefulness) (expressed R²). Investigators usually include a variable with "P" value <0.05 but may include a variable of lesser

significance for varying reasons, particularly if this variable accounts for some of the additional variability and so increases the R^2 of the final predictive equation. Although the "P" and R^2 values are clearly useful they may not in fact be sufficiently sensitive as aids in deciding whether independent variables should be included. The use of other criteria for model selection, particularly Mallows CP, are explored in Chapters 7,8 and 9.

Height and age are the two most important independent variables. The relationship between these two variables is not constant throughout life⁵⁸⁻⁶¹. Schoenberg demonstrated an increase in FVC up to age 24 years, followed by a stable phase to age 35 years and then a steady decline with increasing age⁶¹. Knudson described 3 phases viz: a growth phase (in children younger than 11 years) during which the dominant factors are height and age and both are positive in sign; a second phase of maturation and development (until the ages 20-22 in females and 25 in males) when there is a clear linear relationship of height to age and both signs are positive; and a third phase of adulthood during which there is a slow decline in the parameters and the age co-efficient is negative^{59,60}. The best age group in which to examine various factors that influence lung function is therefore the young adult with mature lungs before decline sets in. Although it is generally accepted that at 25 years the lungs reach their full size, it has also been demonstrated that FVC may increase up to age 35 years. These observations have been supported by longitudinal studies^{62,63}. Longitudinal studies have also revealed that cross-sectional age coefficients are larger than those derived from longitudinal study analysis⁵⁹. This may have the effect that, in simple linear regressions against age, which use a single negative term for age throughout the adult period, over prediction of values of young adults may occur. Use of these equations may have important consequences in determining occupational effects on pulmonary function⁶¹. If a young adult applies for work, pre-employment tests may be considered below normal. If the worker is then employed, significant real function loss on subsequent tests may be overlooked because the rate of decline appears no greater than expected for all adults. Most surveys have shown a decline with age and then a slight increase in the elderly^{58,64-67}.

In considering height as a determinant of lung function, the following observations pertain:

1. Spirometric measurements increase with body size. In adults height is generally as good as powers of height or multiples of height and weight⁶⁸ as a predictor of spirometry.
2. Standing height, is generally accepted to be more predictive of lung volumes than sitting height or trunk length. It is in fact possible that measures of trunk size such as sitting height or sitting/standing height ratio are better predictors of spirometric values^{68,69}, a factor which was examined in the present survey.

It is not clear whether the relationship between FVC and height is really linear over a wide range. It has been shown that individuals more than 75 inches tall have FVC values considerably above the predicted⁶⁸. It has, however, been demonstrated that linear regressions based on height (as a linear influence) do apply to both extremely tall and short individuals (above the 99th and below the 5th percentile)^{70,71}. In the formulation of most prediction equations for spirometric indices age and height are usually used as simple variables. It has been cogently argued that this is mathematically inadequate and that more complex equations using functions of the variables age, height and weight more accurately predict lung volumes, especially in older patients⁶¹. The use of transformed variables has however been investigated and could not be shown to improve the predictability of regression equations. It is more likely that other, as yet undefined, variables such as environmental factors, including social stratification, smoking habits, occupational exposures, as well as genetic endowments, are more important to the development of better prediction equations⁹⁷.

A review of the prediction equations derived from the major spirometric lung function surveys (see Chapter 2) demonstrates the importance of age and measurements of height in their derivation. It is, however, also obvious from the wide range and relatively low R^2 values for these equations that other factors must be important. To this extent, other anthropometric measurements, including weight, muscular development, sex and race have been investigated. Weight has been shown to be positively correlated with spirometric values to the extent that increased weight reflects growth or muscle mass. Beyond this spirometric values decrease with greater weight⁶⁸. Muscular development in persons

whose occupation (e.g. drivers, miners) or hobbies (swimmers and rowers) involve extraordinary physical exertion causes them to have larger FVC values⁷². This increase is thought to be due to an increase in the strength of the inspiratory muscles⁷³. The additional contribution of weight and measurements of muscle bulk do not, however, enhance prediction equations that already include height and age and therefore they are not included. Sex, on the other hand, exerts a powerful influence on lung function values, even when adjustments are made for difference in size. These differences are thought to relate to anatomic or physiologic differences in the components of the respiratory system^{60,68}. Regression analysis performed on data obtained following the separation of sex groups gives rise to better prediction equations for the two separated groups than when the composite is investigated. These results have been consistently demonstrated in many surveys⁶⁸. There can be little argument that a more complete understanding of the determinants of lung function than is presently available is required⁷⁴.

The separation of survey populations by "race" has similarly been demonstrated to improve the R^2 and standard error of the estimate (SEE) values for prediction equations. This has led to the contention that race, like sex, is an important determinant of lung function on the basis of genetic differences. Unlike sex, however, a large amount of overlap has been demonstrated between the different "race" groups (see Chapter 3). In addition, manipulations of height measurements have been shown to reduce and, in certain instances, to eliminate "racial" differences. This has been explained by a greater proportion of the total height in blacks being contributed to by the lower extremities^{68,75,76}. Other studies have, however, shown no difference between the sitting height to standing height ratio (0.50) in blacks and whites⁷⁷. Thus the question whether different race groups have different spirometric volumes is controversial; these differences may (in part) be applicable in terms of height-ratio differences and may (in part) be explicable in terms of social stratification differences. These issues will be examined in depth in the succeeding chapters.

Many authors have recognized the scientific uncertainty regarding reference values for the pulmonary function values for different ethnic groups including blacks in South Africa¹⁻⁶ and that this issue demands further evaluation. Such an evaluation is urgent, since the assessment for disability of black South Africans is complicated by the lack of accurate prediction values.

(d) Problems in using predicted normal values and equations in an individual subject

Predicted values from various published studies vary by as much as 20% for an individual subject⁷⁸ (Chapter 2). Thus a patient's pulmonary function may be thought to be "less than mean normal" with respect to one established reference sample and may be "above mean normal" with respect to a different published reference sample. It has been suggested that there is not one specific value that is normal for individual subjects but a range of values⁵². It is important to realize that a pulmonary function value calculated from a prediction equation should be regarded not as the normal value but the mean of a distribution of normal values. A further factor confounding the use of prediction equations is the well recognised phenomenon of inter-occasion (within subject) variation of lung function. This is generally reported to be in the region of 3% for FVC and FEV₁^{45,52}. Another major problem in the applicability of prediction equations is the variety of testing apparatus used. This factor has been significantly reduced following the ATS standardization project⁵¹. Thus it is important that the clinician should be sure, when interpreting predicted normals, that the equipment used, its calibration and usage all meet the ATS standards. The variations in the standards pertaining to apparatus also cast doubt on "normal" values published prior to the rigid standardisation procedures of ATS were adopted. These considerations are addressed more fully in Chapter 2. It is however important to realize that certain measurements may still be instrument dependent even when the recommended standards for instrumentation are used.

These considerations have serious implications for respiratory disease prevention and for compensation purposes in occupational health. Thus, today there is little agreement in the world literature as to which reference value should be used for control purposes in epidemiological studies and for evaluation of pulmonary disability in individuals for purposes of compensation. Research workers in occupational

lung diseases and clinical laboratories therefore tend to establish their own "normal" values to assess their own populations : this practice would be the only valid approach if wide inter-ethnic differences existed. On the other hand, adoption of a set of local "normal values" may obscure the occurrence of widespread local lung abnormality if, in fact, "racial" factors were of minor significance and environmental factors exerted a decisive influence on the lung function differences between populations.

Viewed epidemiologically, the variation in different prediction equations may be the result of the over-simplification inherent in the assumption that derived regression equations are "predictive". By definition regression equations are descriptive of a specific population and therefore the regression equations available are dictated by the community sampled. The application of these equations to the general population, within the limitations discussed above may, in fact, be erroneous. It is possible that, because of significant influences of environment, equations derived from a population may have only limited general applicability to the community from which the sample was derived, let alone the general population in the future. It may therefore be argued that prediction equations should be derived for specific populations and continually updated.

Prediction equations are therefore highly dependent on the epidemiological methodology used to collect and analyse the data. The difficulties experienced in these studies and the sources of measurement variation will be discussed in the following chapter.

(e) Potential sources of error in establishing normal values in epidemiological studies

Two major sources of variation in lung function tests can be identified, and these will be discussed under the headings: (1) Measurement and (2) Biological.

(i) **Measurement factors**

Measurement errors may be the result of both equipment (instrument) and methodological (observer) failure. It has been estimated, in good laboratories, that approximately 3% of between individual variation for FVC and FEV₁ measurement may be accounted for by technical factors⁵⁷. A good epidemiological study should have no greater proportion of error. Potential sources of technical error include poor instrumentation, poor quality control, effects of temperature and altitude, inappropriate definition of acceptable and reproducible functions, and criteria for selection of "the best curve". Instrumentation has been standardized within the past decade by the American College of Chest Physicians^{47,79} and the American Thoracic Society^{46,51}. By their standards, the spirometer should measure expired volumes of up to 7 L and accumulate volume for at least 10 seconds. Resistance in the circuit of the spirometer should be < 1.5 cm H₂O/L/sec at a flow of 12 L/sec. It has recently been pointed out by the ATS update on spirometry that these standards are the minimum acceptable; the new recommendations also stipulated that the computer software used in modern systems should be validated⁵¹. Quality control guidelines for the maintenance of equipment, calibration and quality control have likewise been published by the ATS⁵¹. Descriptions of these important procedural steps are seldom included in reports of lung function surveys.

It is essential that the equipment and the methodology employed should give both accurate and precise information. Measurement errors have been shown to arise as a consequence of the effects of temperature and altitude. It is currently accepted that lung volumes should be reported at body temperature at the ambient barometric pressure and saturated with water vapour (BTPS). The measurements made by a spirometer are considered to be at ambient (room) temperature (ATPS) and conversion factors have been used to transform the measurements from ATPS to BTPS. Where automated equipment is used the conversion is done automatically by setting the equipment in the BTPS mode. It has been suggested that the use of these correction factors may over-correct the volumes and

that a more accurate conversion is 0.955 of the BTPS factor⁸⁰. The magnitude of this more accurate correction factor is affected by the cooling characteristics of the device.

Scrutiny of the largest investigations into normal lung functions show technical errors, including differing methods of recording lung function. It is currently accepted that the onset of the FVC is defined as the maximum inspiration and the onset of the FEV₁ is defined by "backward extrapolation". This is not the method used by many of the early surveys. The end of the FVC manoeuvre has been defined in only the latest ATS statement published in October 1987. Many spirograms prior to this were terminated before full expiration had been reached. This may have been an important source of error in studies involving different "race" groups whose home language was different to that of investigators, making explanation of procedures difficult.

Another source of error resides in the conventions used for the selection of the most appropriate tracing or measurement for analysis. The most widely accepted method today is the ATS standard for selecting the best of three acceptable readings. Provided the three best traces are acceptable and meet ATS criteria for reproducibility, there is no significant difference if one chooses one curve as the "best" and reports all measurements from the one curve or whether the best FVC is chosen from one curve and the best FEV₁ from the other^{81,82}. Some major studies do not even adhere to this approach (performing spirometry no more than twice) while others do not document their methodology, which makes interpretation of their data difficult, and the application to other studies potentially invalid (see Chapter 2). An "acceptable manoeuvre" is defined as one which demonstrates a "crisp" unhesitating start, followed by smooth, continuous expiration, absence of cough, glottis closure, second inspiration, leak (e.g. at the mouthpiece) or blockage (e.g. by the tongue) and showing complete effort^{51,52}. Measurement errors may also arise from observer variation with respect to both subject and instrument⁸³ as well as a result of poor subject comprehension or cooperation^{84,85}.

(ii) Biologic variation

Biologic variation may be considered to include intra-subject, inter-subject and inter-population variation. The major components of intra-subject variation may be accounted for by measurement variation. Other temporal factors, including circadian or diurnal variation⁸⁶, seasonal variation⁸⁷, climatic factors and, possibly, hormonal influences⁸⁸ may result in intra-subject variation.

(iii) Inter-individual variations

Important inter-individual variations include age and height which have already been dealt with in 1.2.1 (c). The significant role that these variables exert on the derivation of prediction equations for lung functions underscores their importance as sources of biological variation. An important aspect of the influence of stature on biological variation is the importance of studying populations whose body dimensions are not influenced by specific factors. Lung surveys of industrial workers demonstrate greater than expected forced vital capacities⁸⁹. This is due to both the selection of more powerful men into these jobs and is the basis for an important source of biological variation due to the "healthy worker effect"⁸⁹ or 68.

Race has been demonstrated to influence spirometry and this factor is examined closely in Chapter 3.

Smoking is an important cause of between-individual difference. Both acute effects and chronic effects may influence spirometric values^{90,91}. The acute effect of smoking prior to lung function testing is not important in the determination of FVC or FEV₁, but does decrease flow rates⁹². Smokers are much less likely to be "normal" (free of respiratory symptoms and signs) than non-smokers. As expected, the effects of smoking on PFT's have been found to be reduced considerably by analysing only clinically normal subjects^{93,94}. It is, however, important to realize that the analysis of the harmful effects of smoking on lung function in "normal" subjects is very difficult and that statistical analysis of mean data is not very sensitive, because the effect on the susceptible minority may be hidden by the unaffected majority⁹⁵. The chronic effects of cigarette smoking have been demonstrated in a large number of

studies. In a re-analysis of Schoenberg's data, Beck found that the inclusion of variables to quantitate the amount of smoking explained an additional 15% of the residual variation⁹⁰. Ex-smokers, likewise, may be shown to have lower values compared with never smokers⁹⁶. Their functions in most studies have been found to be intermediate between current and never smokers. Besides these well documented effects of direct smoking, studies (recently reviewed by Steinberg⁹⁷) have suggested that environmental exposures related to home conditions (including passive smoking exposure) and work place may be important⁹⁸.

Spirometric functions display circadian and diurnal rhythm^{86,99}, rising in the morning to a maximum in the afternoon and falling to a minimum during the night. These variations are small but may introduce a precision error when comparing two groups. In addition, FVC may vary with the hours of daylight and with the seasons⁸⁷.

Other accepted causes of inter-subject variation include past health experiences (e.g. childhood illnesses)^{100,101}, genetic characteristics (e.g. twins and alpha 1 antitrypsin deficiency)¹⁰², hormonal factors⁸⁸ and the work environment¹⁰³.

(iv) Inter-population Variation

All the above factors will of course contribute to between-population differences. A major source of variation is found in selection into and out of the population which is chosen for an epidemiological study. A population chosen for an epidemiological study interested in examining determinants of lung function should be a "normal" population which is "representative" of the population in whom the data is ultimately to be used. Major problems in studies giving rise to the normal values for adults include the unscientific sampling of subjects, differences in opinion as to whether "normal" or "general" subjects should be studied and the difficulty in defining "normal subjects" or "normal values".

The concept of "normality" is open to wide differences in interpretation. Becklake⁵, in her authoritative review of the subject, points out that not only does the word normal vary with the context in which it is

used, but the fact that neither health, nor disease have generally accepted definitions leads to the differences in the approaches adopted by investigators interested in measuring normal physiological values. Researchers in this field usually aim not only to exclude obvious pathology, but also exclude subjects who have been exposed to an adverse respiratory health effect. Although the American Thoracic Society has proposed guidelines¹⁰⁴ as to what may be considered an "adverse respiratory health effect" in response to environmental pollution, a succinct definition of an adverse effect and a methodology to screen for this effect are not available.

In general, most authors have defined their normal populations as those from which abnormal subjects have been excluded by means of screening. Thus, identification of a "positive history" has been used as an important step in screening the population. The definitions of normality used by each of the major studies from which spirometric prediction equations have been derived are summarised in Chapter 2. The definition of a "positive history" has varied from, simply, "chronic bronchitis" to the other extreme where it has been suggested that history (or electrocardiographic evidence) of coronary artery disease should exclude subjects from a normal population, since such people have a lower FVC and FEV₁^{105,106}. Individuals have been excluded from the major lung function surveys for various reasons, including an objectively obtained history of respiratory (sometimes including cardiac) disease and symptoms^{58,60,64,66,67,71,93,107-110} abnormal clinical examinations^{66,67}; an abnormal chest radiograph¹⁰⁹; smoking^{58,60,64,66,71,122,123,108-111} or history of previous, or current, exposure to known pulmonary hazards^{66,111} (see also Chapters 2 and 3).

A population that is defined as being normal may, in fact, be "supernormal" or "ideal" but not representative of the general population. A representative population is one which reflects the distributions of lifestyles, symptoms, specific disease states, smoking habits, occupational or environmental exposures and the races a community. In order to minimize bias, the normal group should be selected from a random sample of the population to be studied. As will be shown in Chapter 2, many series have carefully defined their subjects as "normal" but have not ensured that their sample is

representative. Many studies have relied on volunteers coming forward. This practice casts doubt as to the validity of such series being representative of an overall population as the volunteers may have had "their own reasons" for coming forward.

Although a population may be representative of a general population, it is important that its precise composition is well described. In most studies the true composition of whites and blacks and the criteria used for this distinction is usually not specifically defined. Some series have limited the study to a narrow national origin, whereas others make some attempt to differentiate between race and ethnicity. Race and ethnicity are terms that are used interchangeably, and often incorrectly, by most investigators. This is partially because of the unpleasant connotation that has developed with the use of the term race and also the confusion that exists as to the definition of these terms. These aspects are expanded on in Chapters 3 and 4.

Another important source of between population variation is the manner in which studies have varied in their utilization of data from subjects who smoke, as well as in the definition of what constitutes a smoker. In some studies which included smokers the authors argued that their inclusion was necessary because they are attempting to provide prediction equations for an "average population" in whom smokers will be found⁶⁶. Variation in the definition of a smoker is best illustrated by the extreme example of a study by Bass¹⁰⁸ who excluded smokers, but defined their subjects as smokers only if they smoked more than a pack of cigarettes a day for more than 5 years. Many of the studies giving rise to racial differences in lung function have included smokers in one or both of the race groups (see Table 3 (i) Chapter 3). This clearly confounds comparisons of racial differences in lung functions.

1.2.2 Transfer factor (TLCO_{SB}) (syn. diffusing capacity) normal value determination

(a) The role of prediction equations and reference values (TLCO_{SB})

The single breath carbon monoxide diffusing capacity of the lung (TLCO_{SB}) and its correction for lung volume DL/VA is commonly measured as part of diagnostic lung evaluations and epidemiological

surveys. The $TLCO_{SB}$ is the only easily performed non-invasive test of lung function that yields information on the gas exchange functions of the lung. Reduced transfer factor may be present when spirometry and radiological examinations are normal although the converse may be true. The measurement is particularly useful in the diagnosis of pulmonary fibrosis and emphysema. It is also suggested that the transfer factor may be able to detect early lung parenchymal changes and for detecting early destructive causes of airflow limitation¹¹²⁻¹¹⁶. The usefulness of the test has also been established in the assessment of patients with suspected disease in occupational and population surveys⁴⁰. It is generally accepted that racial differences do not exist, although Rossiter has suggested that a scaling factor (8% reduction of normal values for whites) be used for black subjects¹¹⁷. Measured values are usually assessed in terms of normal values obtained from equations that take height and age into account. Such equations are usually based on data from studies of healthy reference populations^{29,118-124}. Transfer factor and its correction for lung volume (DL/VA) are often expressed as a percentage of predicted using the prediction equations available. It is thus essential to be sure that the application of a given selected predicted equation is valid in the populations under study.

(b) Potential sources of error in measuring $TLCO_{SB}$ in epidemiological studies.

(i) **Measurement variation**

The measurement of transfer factor by means of the single breath diffusing capacity for carbon monoxide has numerous potential sources of error. These problems have been extensively reviewed and recommendations made in order to lessen the sources of error, as well as to standardize measurement techniques.^{30,46,49,57} The current ATS recommendations are presented in Chapter 5, alongside the methodology used in this current investigation⁵¹. It is, however, important to realise that currently available normal values are derived from studies that differ, not only in measurement techniques, but also in their use of acceptable equipment and measurement techniques.

The major sources of measurement variation include (1) testing methodology⁵⁶, (2) errors in gas analysis^{56,125,126} and (3) computation software.¹²⁷ The large variations in measured $TLCO_{SB}$ and

therefore predicted $TLCO_{5B}$, is compounded by variations in interpretation⁴⁰. The two gases most frequently employed are carbon monoxide (CO) and Helium (He). Helium is measured by a katharometer, which should be linear and accurate within $\pm 1\%$ throughout the range required.

Carbon monoxide may be measured by either the traditional infrared sensor or the modern rapid and stable, electrochemical (fuel cell) analyser. The latter responds more rapidly, is more stable and has simpler architecture. Infra red devices for measuring CO concentrations are non-linear, but modern instruments have computer software or circuitry to linearise them.³⁰ It is essential that the type of analyser used is known and that the meters are documented to be linear and in the case of a non-linearised CO meter that the calibration curve of the specific instrument is known. This is most easily accomplished by sequential gas dilution or using test gases of known concentrations.³⁰

In addition, further errors may occur as a consequence of the effect of CO_2 and H_2O on the analysers. CO_2 affects the readings of both infra red CO analysers and He katharometers. The latter are also adversely affected by H_2O ; produced by both the subject and by the reaction of CO_2 with its absorber (either $Ba(OH)_2$ or $NaOH$). It is thus essential that the position of these absorbers is stated by investigators and that the appropriate corrections are made to analyser measurements.³⁰

The technique used should adhere to accepted standardization recommendations. A problem however exists in that there are discrepancies between the major coordinating bodies with respect to certain aspects of the methodology^{30,52}. Thus different investigators have either followed different recommendations or have attempted to adopt combinations of these standards (see Chapter 2). The most recent ATS statement summarises the potential sources of methodological variation and makes recommendations which appear to offer the best chance of standardisation³⁰. Important aspects of this statement will be discussed in the following paragraphs.

The traditional apparatus utilises a bag-in-box system in which a bag (filled with the test gas mixture) is placed within an airtight box so that a change in volume can be measured by a spirometer.¹²¹ More modern systems dispense with the bag and instead supply the inspirate directly from gas cylinders, utilising a demand valve system. A pneumotachograph and integrator are used to measure the volumes. These systems have the advantage of saving time but require more sophisticated instrumentation. These tend to drift and their linearity and accuracy needs to be constantly assured at the different flow rates³⁰.

The automation of equipment by means of computational software has greatly improved the ability of laboratories and investigators to standardise the technical aspects of TLCO_{SB} determination. Automated systems provide relatively constant breath hold time, dead space volume and volume sample capture. It is important the software should be accurate and calibrated correctly³⁰.

TLCO_{SB} measurement alters with the duration of breath hold time,^{28,128,129} and this has been standardised³⁰.

The condition under which the inspired gas (V_I) and alveolar volume gas (V_A) are considered to exist is another major source of measurement variation in epidemiological studies. In most cases investigators have assumed the inspired gas to be ATPS⁴⁵. This is in fact not usually the case; ATPD (i.e. dry or unsaturated) is the most usual condition (unless the test gas is transferred initially to a water-sealed spirometer)⁵². Morris, in a recent study, has demonstrated that TLCO_{SB} calculated with V_I at ATPS rather than at ATPD (when in fact these are the prevailing conditions) is underestimated by 3% at sea level and by 4% at 1400m. It is therefore important that investigators specify the inspired gas conditions of their instruments. A similar problem exists with the alveolar volume V_A . V_A is reported either at BTPS or STPD.^{130,131} It is currently recommended that V_A be expressed at BTPS^{47,52}, when expressed in this way DL/V_A is independent of altitude.^{40,30}

The coefficient of variation of $TCLO_{SB}$ in normal subjects may be as much as 5-6% with manual systems or 3-4% with automated systems.¹²¹ It is therefore important that investigators ensure accurate measurements in order to yield reproducible results. Acceptable criteria for reproducibility are two tests with 10% or 3ml (CO (STPD) $\cdot\text{min}^{-1}$ mmHg⁻¹, whichever is larger. It is also important that the mean of 2 acceptable tests be reported^{30,52}.

(ii) Subject variation

Transfer factor determinations are affected by the following physiological considerations:

The accuracy of single breath transfer factor measurement is affected by both inter- and intra-individual variation, as well as inter-population differences. Inter-individual factors may cause significant variation. The important sources of biologic variation include the following: age, sex, stature, position, lung volume, smoking, haemoglobin level, time of day, exercise and nutritional status.

Transfer factor in adults decreases in a linear fashion with age and increases in a linear position with height^{29,118-124}. This has been shown by Miller and Georges to be in the region of a 31% and 29% decrease over the span 20-70 years respectively^{123,132}. The relationship of DL/VA with age and height is not certain. Some investigators have demonstrated no inverse relationship^{122,123}. An inverse relationship with height has been found by some investigators^{122,131}.

Transfer factor varies with sex, being generally lower in females than males^{122,123}. DL/VA is, however, not related sex¹²².

Single breath determinations are greatly influenced by body position. By convention, single breath is measured in the upright sitting position. Increased values are found in the supine position due to the increased perfusion of the upper zones of the lungs.¹³³ DL/VA determinations likewise demonstrate a

15.6% difference between supine and upright positions in normal non-smokers.¹³⁴ DLCO and DL/VA also decreases from the seated to the standing position.²⁸

Transfer factor is influenced greatly by the actual lung volume as well as the volume utilised during the test. The greater the lung volume the greater the $TLCOSB$.¹³³ The measure of transfer factor does however decrease in a non-linear fashion as the lung volume at which the breath is held is decreased. This close relationship between effort and result was first noted by Krogh²⁴.

A diurnal variation in the region of 1.2% per hour in the morning and 2.2% per hour in the evening¹³⁵ has been demonstrated. This variation was found to be independent of catecholamine and the diurnal variation in lung mechanics.

Cigarette smoking has been shown to exert a profound effect on transfer testing. In otherwise normal people progressively lower levels are found in normal versus previous and current smokers. This may be due to sub-clinical destruction of the pulmonary parenchyma, but the pathogenesis has not been fully explained^{118,120,123}. The acute effect of smoking is also an important influence on transfer factor. Smoking results in an increased carboxy haemoglobin.¹³⁶ The back pressure exerted by carboxy Hb tends to decrease measured transfer factors.¹³⁷ The most common cause for an increased CoHb is smoking,¹³⁸ although certain atmospheric pollutants may also raise the level.^{139,140} It is important to either measure the CoHb or to be certain that subjects have not smoked within the 2 hours prior to testing. The ATS update recommends that the subject be asked to refrain from smoking for 24 hours before the test to reduce the carbon monoxide back pressure¹³⁰. This is virtually impossible to apply in an epidemiological survey.

An important component of the gas exchange process of the lung is the available haemoglobin. It is therefore not surprising that haemoglobin concentration greatly influences the transfer factor, increasing the measurement in proportion with haemoglobin.¹⁴¹ It is essential to take this factor into account in

evaluating the results of a survey³⁰. If Hb adjustments are made, the ones of Cotes¹⁴² are recommended³⁰.

Exercise increases the cardiac output, so increasing pulmonary capillary recruitment and pulmonary perfusion, so increasing the transfer factor¹⁴³. It is therefore important that the measurements be done on well rested individuals. Transfer factor has correlated with nutrition as expressed as the percent ideal body weight in patients with emphysema¹⁴⁴. It has been suggested that the test should not be performed within two hours of a large meal and subjects should also avoid alcohol for at least four hours before testing¹⁴⁵.

(iii) Inter population differences

Inter-population differences will of course be contributed to by all the above. Certain specific considerations pertinent to the evaluation of normal prediction values will be presented here. The major problem that continues to hinder epidemiologic surveys is the lack of uniform methodology of selection, size and characteristics of the population surveyed, as well as the testing methodology used. The absence of standardisation makes it difficult to compare values obtained in different laboratories. Surveys including smokers will produce prediction equations which are lower than those obtained from non-smokers.

The altitude at which a study is performed is particularly important in the evaluation of transfer factor. Altitude effects include increased haemoglobin concentrations and lowered inspired oxygen tensions. DLCO and DL/VA are dependent on both haemoglobin concentration and oxygen tension^{146,147}. It is therefore important to measure haemoglobin and correct if necessary. It has also been recommended that at high altitudes either an increased FIO_2 or correction factor should be used.^{130,148} It is important to put the effect of altitude into perspective. It has been demonstrated that $TLCOS_B$ ^{149,150} is increased in natives living at altitudes greater than 3000 metres compared to those at sea levels. It has, however, also been suggested that an acclimatized low-lander does not have an increased TLCO at high altitudes.

It is not clear whether intermediate altitudes (\pm 1500 m) have a corresponding intermediate value if significant hypoxia does not occur, although a recently published study by Gray et al would suggest that this is the case¹⁵⁰.

(c) Methodologic shortcomings in published predicted normal values of TLCO_{SB}

In summary, the major problems with published prediction values for single breath include the following: Most of the early studies included very small numbers of subjects selected by haphazard techniques and therefore not necessarily representative. Many of these studies mixed smokers with non-smokers and therefore produced lower than expected normal values. The methodology of surveys lack standardization so that the results are not comparable. The effect of smoking is not fully understood and therefore modern surveys have attempted to produce different sets of normals, depending on smoking status. Use of these smoking-specific reference values permits the effects of cigarette smoking to be distinguished from the effects of other disease processes and environmental exposures. Classification of smokers is, however, not always uniform, which complicates the interpretation of these values. The effect of altitude remains controversial regarding the general applicability of normal values obtained at different altitudes. As a result of these sources of variation, the values predicted by the various equations vary widely.

It has been suggested that while such confusion exists, laboratories should establish the most appropriate normal values to their laboratories by measuring a small sample (15) of normals¹⁵¹. This is clearly an unsatisfactory situation as it does not allow for inter-laboratory comparisons. The Epidemiology Standardisation Project published guidelines for measuring transfer factor. The proposals regarding transfer factor do not appear to have been as widely accepted as those for spirometry. The most recent ATS update of 1987⁵¹, has attempted to deal with the criticisms arising from the earlier (1979)⁴⁵ report and may lead to better standardisation in the future.

1.3 THE DETERMINATION OF NORMAL VALUES FOR TOTAL LUNG CAPACITY

Total lung capacity, functional residual capacity and residual volume form the principal components of static lung volumes. Total lung capacity is not commonly performed in epidemiological studies, since it is a relatively more difficult test to perform. The test requires sophisticated apparatus, a trained technologist and sufficient time. It has little value in detecting restrictive pathology, although it is useful in the confirmation and quantification of obstruction and in distinguishing obstructive and restrictive elements in combined disease. As a result there are few published studies of prediction values.

Problems with prediction values

The determination of normal values are subject to all the difficulties outlined previously for spirometry and transfer factor and will not be re-examined in this section. A very wide variation in the predicted values generated by the different equations is evident as illustrated in Chapter 2. The variation for residual volume has been shown to be of the order of 1 l and for total lung capacity 3.5 L⁶³. A major source of variation resides in the variety of instruments used⁷⁵. The most commonly used references are based on multiple breath dilution techniques. Variations in the duration of time allowed for equilibration (not often stated) contributes to the wide range of values produced. Many laboratories use newer techniques including plethysmographs or radiographic methods. These other techniques tend to give higher values than the dilutional technique⁷⁵. Another problem is that the studies are usually based on a small sample of mixed smoking status and thus factors influencing TLC and its sub-divisions have not been carefully studied. Interpretation in the clinical setting is further confused by the use of different prediction equations for spirometric measurements and for static volumes despite their dependence on each other. The major studies utilising the Helium dilution technique are reviewed in the next chapter and summarised in Chapter 3.

CHAPTER 2

2. REVIEW OF SELECTED MAJOR LUNG FUNCTION SURVEYS

2.1 INTRODUCTION

Discrepancies between the pulmonary functions of different investigations are well documented. The preceding chapter outlined the background of this situation. It has already been shown (in Chapter 1) that among the causes of variation in spirometry, marked differences between whites and blacks have been demonstrated by many investigators. Several of these may be regarded as authoritative studies and their data have been adopted by laboratories for use as normative values. It is important to assess these surveys with the following points in mind. The majority of surveys that examine black and white groups conclude that whites have larger lungs because of genetic factors. In reaching these conclusions the onus rests on these authors to exclude factors, other than race, that might influence lung function at varying degrees in the racial groups.

The following factors were considered in the appraisal of the major lung function studies which follows:

(a) Selection bias

In the selection of the study population and the sub-group that is finally used for analysis, attention should be given to the age distribution (differences of opinions exist as to when the lung may be considered mature and the effects of nutrition on this), environmental pollutant exposure (including domestic fuels and occupational exposure), smoking habits (particularly the definition of a "smoker", whether only never smokers or current non-smokers, including previous smokers, are analysed or whether smoking status is not taken into account at all) and the history of previous serious chest disease (including tuberculosis, bronchiectasis, chronic bronchitis, etc).

An ideal selected sample for generating generalizable reference values for lung function will have:

- (i) a population that has been selected from a random sampling of the general population;
- (ii) a representative population that reflects the distribution of population groups, lifestyles, symptoms, disease states, smoking habits and occupation or environmental exposure should reflect that of the general population being studied;
- (iii) a "normal" population who may be defined by:
 - (a) a negative smoking history (i.e. lifetime never smokers),
 - (b) absence of cardio-respiratory symptoms,
 - (c) absence of significant past or present cardiorespiratory illness,
 - (d) no past or present history of exposure to known adverse respiratory influence in either the work or home environment,
 - (e) the absence of a history of significant childhood illness or adverse childhood influences including poor nutrition or housing conditions.

All studies that are quoted in the subsequent pages will be criticised in the light of the above idealised sample selection criteria.

(b) Definition of study population

It is important that authors define their populations in detail. This is particularly important in two regards. Firstly, when racial groups are studied the race groups should be defined accurately (not simply in terms of skin colour), with objective data provided as to their relative origins, social class, place of residence and exposure to adverse respiratory health risks. In all studies data relating to these latter points should also be provided in order that interpretation of results can be enhanced and comparisons more accurate. Chapter 4 considers the concept of "race" in detail. Secondly, it is vital that if normal subjects are screened, the criteria of "normality" that are used be stated and that the relationship of this normal group to the population from which they were selected also be clarified.

(c) Role of socio-economic class and environment

Even when the above overt potential causes of lung dysfunction have been matched, more subtle influences such as passive smoking or the complex effects of a socio-economically disadvantaged environment may impact on pulmonary functions. It will be seen that in an attempt to study homogeneous population groups with assumed similar environmental and socio-economic factors, many studies have been devised from population bases which were too narrow to permit valid generalisation. Other surveys have examined large numbers of subjects sampled in such a way as to be representative of the communities in which they live. Consideration should be given as to whether the subjective assessments are borne out by objective analysis.

(d) Differences in analysis and methodology of obtaining data

The vital role of the American Thoracic Society's criteria⁵¹ in rejecting the inclusion of data of subjects that do not satisfy minimum criteria for lung function testing has already been discussed. It is important to ensure that surveys adhere to this as a minimum requirement. Deviation from these is likely to lead to the inclusion of misleading data. It is important to examine the role that an adverse socio-economic background, manifesting through lack of education may have on the performance of lung function tests and so result in a systematic bias if ATS criteria are not rigidly applied.

(e) Differences in statistical analysis

It is important to examine the methods of analysis in order to assess the likelihood of bias in relation to the "correction factors" that are used. Despite the well accepted role of age in predicting lung function, it is important to be sure that age is correctly recorded. In disadvantaged communities worldwide, and in South Africa in particular, birth records are not accurately kept and individuals' ages may be subject to human error.

Accuracy of age is particularly important because if linear regressions are used to describe the age-related changes in studies confined to adults (with mature lungs), over prediction of values in

younger age groups are likely. The use of standing height is generally accepted as the most accurate determinant of lung function. It will however be seen that sitting height and standing/sitting height ratios may be more appropriate. The age-related changes in the younger age groups (while lungs are still maturing) are in fact best described by non-linear models.

It is generally accepted that following a period of growth and maturation, lung function begins to decline¹⁵². The age at which this decline commences is not, however, certain and may depend on several factors¹⁵³.

2.2 MAJOR SELECTED STUDIES AND THEIR PROPOSED REFERENCE VALUES FOR SPIROMETRY

The comparison of measured lung function with reference values derived from published data on healthy populations is necessary given the many factors, other than disease, that focus on clinical assessment and contribute to the between-individual variation in lung function⁵. Miller, however, highlights a difficulty arising from comparisons of studies with large numbers of subjects: small differences in the distribution of values may be statistically significant, even when the tests themselves have great variability (e.g. flows at low lung volume). Thus, "statistically significant" does not necessarily mean "clinically important"⁵⁰. Some studies do not quote the multiple correlation coefficient or standard error of the estimate, so making their results difficult to evaluate. Nevertheless, this review is presented in order to evaluate the basis for the acceptability of the normal values that are commonly used in laboratories. A review of these most commonly recommended and used equations is now presented. The methodology, conclusions and pitfalls of these studies are presented in Tables 2 (i) - 2 (iv). Additional comments regarding these surveys are made in the text that follow. Where necessary, comments regarding several other studies are also included in the text. The studies selected for this review are based on the most widely used prediction formulae in South Africa and the most oft quoted references in the American and South African respiratory literature. Certain studies which in previous generations were held in high regard, but have been superseded following the modern standardisation

TABLE 2 (i): MAJOR STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR ADULT MALES HAVE BEEN DERIVED

AUTHOR		LOCATION		POPULATION					NORMALITY SCREEN								
NAME REF	NO.	SITE/ (ALTITUDE)	YEAR PUB	TOTAL N	BLACK MALES N	WHITE MALES N	POP. BASE U/R C/B S/B	SELECTION CRITERIA	AGE MEAN (RANGE)	> 25 - < 65 YRS N	DATA NON-ATTENDERS	CXR PA/L FS/M	QUEST. I/V TECH.	OCCUP. HISTORY	SMOKING STATUS	CLIN. EXAM	NORMAL POPULATION (DEFINITION)
Bass 108	01	Boston USA (NS)	1973	247 M+F (NS)	-	149 (NS)	NS NS	Volunteers	NS 21->71	109 >30<70	NS	Yes NS	MRC NS	NS	Yes Mixed	Yes	Non-smokers < 1pkt/day for 5 years No abnormalities on history/CXR/Exam
Black 109	02	Minnesota USA (1400)	1974	193 M+F (NS)	-	83 (49)	NS NS	Haphazard	NS 24 <20-60	NS	NS	Yes NS	NS NS	NS	Yes Mixed	Yes	Negative CXR No history cardio-pulmonary disease No SOB on hurrying up a hill No cough/phlegm/wheeze
Crapo 71	03	Salt Lake USA (1400)	1981	311 251M+F (125M)	-	125 (NS)	U C/B	Volunteers	49.2 835.3	74	NS	Yes NS	BMRC Self	NS	Yes Excluded	Yes	Lifetime non-smoker (< 0.5 pk/year) No symptoms lung/heart /chest wall disease Normal CXR Normal exam
Cherniack 111	04	Manitoba Canada (NS)	1972	1322 M+F (NS)	-	NS (870)	U C/B NS	NS	NS 15-79	223 >30<70	NS	NS	MRC Mod	NS	Yes Never	NS	Never smoked No chronic cough/phlegm/SOB/wheeze No history chest injury

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; Pop Base = Population based; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based; CXR = Chest radiograph; PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 2 (i) (continued): MAJOR STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR ADULT MALES HAVE BEEN DERIVED

AUTHOR	LOCATION	POPULATION				NORMALITY SCREEN										
		SITE/ (ALTITUDE)	YEAR PUB	TOTAL N	BLACK MALES N	WHITE MALES N	POP. BASE U/R	SELECTION W/B C/B	AGE MEAN (RANGE)	> 25 - < 65 YRS NON- ATTENDERS N	DATA	CXR PA/L FS/M	QUEST. I/V TECH. HISTORY	SMOKING STATUS	CLIN. EXAM	NORMAL POPULATION (DEFINITION)
Dockery 110, 162	6 Cities USA (NS)	1985	11040 M+F (2454 M+F)	- 242	(NS) (647)	U	C/B	Random selection plus volunteers	NS	Yes	NS	NS	MRC Non- Medical	Yes Never	NS	White asymptomatic Never smokers No wheeze/asthma/SOB/ recurrent illness/ cough/phlegm > 3 months for 3 years
Ferris 107	Berlin New Hampshire USA (1100 ft)	1964	1216 (NS)	- (125)	592 (125)	U	C/B	Random probability sample + volunteers	NS	NS	NS	NS	CIBA Phys (x5)	Yes Non + Current	NS	No history cough/SOB/ phlegm/wheezing most days or nights FEV1 > 60% of FVC
Ferris 107	As above	1967	311 251M+F (125M)	- (119)	477 (119)	U	C/B	As above (follow-up)	NS	Yes	NS	NS	MRC Non- Medical	Yes Yes	NS	As above

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; Pop. Base = Population based; Work based; C/B = Community based; S/B = School based; H/B = Hospital based;
 CXR = Chest radiograph; PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 2 (i) (continued): MAJOR STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR ADULT MALES HAVE BEEN DERIVED

AUTHOR	LOCATION	POPULATION				NORMALITY SCREEN										
		SITE/ (ALTITUDE)	YEAR PUB	TOTAL N	BLACK MALES N	WHITE MALES N	POP. BASE U/R	SELECTION W/B C/B	AGE MEAN (RANGE)	> 25 - < 65 YRS NON- ATTENDERS N	CXR PA/L FS/M	QUEST. I/V TECH. HISTORY	OCCUP. STATUS	SHOKING CLIN. EXAM	NORMAL POPULATION (DEFINITION)	
Knudson 58, 59	Arizona USA (1400)	1976	3385 M+F (746)	-	NS	U	C/B	Random sample	86 >25<90	NS	NS	Nurses	No	Yes	No	No history heart trouble No childhood resp problems Not pregnant No current cough/SOB/ phlegm Non-smokers -ve skin prick/blood
Kory 21	USA	1961	468 (NS)	83 (49)	U	H/B	NS	NS	37.3 420	NS	Yes NS	NS	NS	Yes Mixed	Yes	No history chronic or acute cardi- pulmonary disease last 6 months Normal exam/CXR Able to cooperate No manifest weakenss No condition with resp component

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; Pop Base = Population based; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based;
CXR = Chest radiograph; PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 2 (1) (continued): MAJOR STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR ADULT MALES HAVE BEEN DERIVED

AUTHOR		LOCATION		POPULATION				NORMALITY SCREEN								
NAME REF	NO.	SITE/ (ALTITUDE)	YEAR PUB	TOTAL N	BLACK MALES N	WHITE MALES N	POP. BASE U/R	SELECTION W/B C/B	AGE MEAN (RANGE)	DATA > 25 - < 65 YRS NON- ATTENDERS N	CXR PA/L FS/M	QUEST. I/V TECH.	OCCUP. HISTORY	SMOKING STATUS	CLIN. EXAM	NORMAL POPULATION (DEFINITION)
Morris 65, 65, 165	09	Oregon USA	1970	988 M+F (988)	-	517 (509)	R Mormon 7th Day Adv 24%	NS 55%	NS	389	NS	Yes NS	NS Self	Yes Yes Never	Semi	Never smoked > 6 months Never asthma/chronic bronchitis/pneumonia Never persistent cough /wheeze No recent respiratory disease Never lived polluted atmosphere
Schmidt & Dickman 66, 154	10	Utah USA (NS)	1973	757 M+F (532 M+F)	-	229 + 66 ex	R SCG Volunteers	NS	NS	-	NS	Yes Mobile	BMRC Self 115	Yes Mixed	Yes	History symptoms/signs of heart disease, asthma, emphysema, other lung diseases CVA/thoracic surgery Chest abnormalities Poor general health

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; Pop Base = Population based; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based; CXR Chest radiograph; PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 2 (i) (continued): MAJOR STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR ADULT MALES HAVE BEEN DERIVED

AUTHOR	LOCATION	POPULATION				NORMALITY SCREEN								
		TOTAL N	BLACK MALES N	WHITE MALES N	POP. BASE U/R W/B C/B S/B	SELECTION CRITERIA	AGE MEAN (RANGE)	DATA > 25 - < 65 YRS NON-ATTENDERS N	CXR PA/L FS/M	QUEST. I/V TECH.	OCCUP. HISTORY	SMOKING STATUS	CLIN. EXAM	NORMAL POPULATION (DEFINITION)
Schmidt & 10a Dickman 66, 154	Utah USA 4500 ft & 6500 ft	NS (604 M)	-	604 (49)	U H/B	Volunteers	38.7	NS	NS	NS	NS	NS	NS	Stated good health
Schoenberg 11 61, 63	Connecticut USA	NS (1136 M+F)	NS 120	NS 194	U + R C/B	NS	48.6 (20-94)	124W 65B	NS	NS	NS	NS	NS	No cough/sputum disability/dyspnoea wheezing No asthma Lifetime non-smokers atmosphere

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; Pop Base = Population based; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based; CXR = Chest radiograph; PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 2 (ii): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR ADULT MALES HAVE BEEN DERIVED: TESTING METHODOLOGY

AUTHOR		TESTING METHODOLOGY						
NAME	NO.	EQUIPMENT	TECHNOLOGIST	NO. OF TRIALS	SELECTION CRITERIA	FEV1 STARTING POINT	ATS STANDARDS	BTPS CORRECTION
Bass H	01	Wedge Spirometer	NS	2 (1 practice)	NS (? best)	NS	No	NS 6
Black	02	Body plethysmograph	NS	2 (1 practice)	Best	NS	No	Yes
Crapo	03	Water-seal spirometer	NS	3 accepted	Best	Back extrapolation	Yes	Yes
Cherniack RM	04	Portable wedge Spirometer	Trained	3 or more	Best	Threshold	No	Yes
Dockery	05	Portable Stead Wells water 8L spirometer x 14	NS	Numerous	Average best 3	Back extrapolation	No	Yes

NS = Not stated; FEV1 = Forced expiratory volume in 1 second; ATS = American Thoracic Society; BTPS = Barometric Temperature and Pressure

TABLE 2 (ii) (continued): MAJOR STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR ADULT MALES HAVE BEEN DERIVED

AUTHOR		TESTING METHODOLOGY						
NAME	NO.	EQUIPMENT	TECHNOLOGIST	NO. OF TRIALS	SELECTION CRITERIA	FEV1 STARTING POINT	ATS STANDARDS	BTPS CORRECTION
Ferris BG	06	Collins 6L Vitalometer	Physicians	5	Mean last 3	Back extrapolation	No	Yes
Ferris BG	06a	Stead Wells watermeter spirometer	Physicians	5	Mean last 3	Back extrapolation	No	Yes
Knudson	07	Portable Pneumotach	NS	5 (min)	Best of first 3	Back extrapolation	No	Yes
Kory	08	Collins water Spirometer (13.5L)	NS	Multiple	Average of best 2 trials	Kory	No	Yes
Morris JF	09	Stead Wells water spirometer (6)	Trained	2 (min)	Best	Kory	No	Yes

NS = Not stated; FEV1 = Forced expiratory volume in 1 second; ATS = American Thoracic Society; BTPS = Barometric Temperature and Pressure

TABLE 2 (ii) (continued): MAJOR STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR ADULT MALES HAVE BEEN DERIVED

AUTHOR		TESTING METHODOLOGY						
NAME	NO.	EQUIPMENT	TECHNOLOGIST	NO. OF TRIALS	SELECTION CRITERIA	FEV1 STARTING POINT	ATS STANDARDS	BIPS CORRECTION
Schmidt	10	Collins 13.5L Spirometer	Trained	At least 3	Best	Kory	No	Yes
Dickman	10a	Stead Wells watermeter spirometer	Trained	NS	NS	Kory	No	NS
Schoenberg	11	Pneumotachograph		5	NS	Back extrapoliation (Computer)	No	Yes

NS = Not stated; FEV1 = Forced expiratory volume in 1 second; ATS = American Thoracic Society; BIPS = Barometric Temperature and Pressure

TABLE 2 (iii): PREDICTION EQUATIONS (SPIROMETRY) FOR ADULT MALES

AUTHOR		REGRESSION (PREDICTION) EQUATIONS		STATISTICAL TESTING			PREDICTED NORMAL		
NAME	NO.	FVC (WHITE) FVC (BLACK)	FEV1 (WHITE) FEV1 (BLACK)	R ²	FVC SEE	R ²	FEV1 SEE	FVC (W) FVC (B)	FEV1 (W) FEV1 (B)
Bass H	01	-5.72 - 0.023A + 0.159H in 0.92 10.64	-	0.64	0.60	-	-	4.63	-
Black	02	-1.306 - 0.028A + 0.042H cm +0.603 - 0.032A + 0.027H cm	-	0.45	0.51	0.69	0.46	3.62 4.71	2.71 3.91
Crapo	03	-4.650 - 0.0214A + 0.0600H cm -2.190 - 0.0244A + 0.0414H cm	-	0.54	0.64	0.64	0.486	4.69	3.87
Cherniack	04	-3.184 - 0.0136A + 0.12102H in -1.5073 - 0.0232A + 0.0910H in	-	0.49	NS	0.55	NS	4.36	3.65
Dockery	05	$(-0.0001008A^2 - 0.00135A + 1.750 - 0.287\text{sex})H^2\text{m}$ $(-0.0000614A^2 - 0.00406A + 1.54 - 0.209\text{sex})H^2\text{m}$	-	0.77	0.47	0.770	0.398	4.44	3.69
Ferris	06	-2.79 - 0.027A + 0.046H cm -0.70 - 0.028A + 0.029H cm	-	0.63	0.66	0.61	0.59	3.95	3.11

A = Age (years); H = Standing height; in = inches; cm = centimetres; m = metres; FVC = Forced vital capacity; FEV1 = Forced expiratory volume in 1 second; R² = correlation coefficient; SEE = Standard error of estimate; L = Litres; W = White; B = Black; Sex 0 = male, 1 = female

TABLE 2 (iii) (continued): PREDICTION EQUATIONS (SPIROMETRY) FOR ADULT MALES

AUTHOR		REGRESSION (PREDICTION) EQUATION		STATISTICAL TESTING			PREDICTED NORMAL		
NAME	NO.	FVC (WHITE) FVC (BLACK)	FEV1 (WHITE) FEV1 (BLACK)	R ²	FVC SEE	R ²	FEV1 SEE	FVC (W) FVC (B)	FEV1 (W) FEV1 (B)
Ferris BG	06a	-1.163 - 0.040A + 0.041H cm - 0.006(cigs/day)	+0.588 - 0.041A + 0.027H cm - 0.010 (cigs/day)	NS	NS	0.55	NS	4.21	3.53
Knudson	07	-8.782 - 0.0298A + 0.0844H cm	-6.515 - 0.029A + 0.665 Hcm	0.72	NS	0.58	NS	4.37	3.63
Kory	08	-3.60 - 0.022A + 0.052H cm	-1.59 - 0.028A + 0.037H cm	0.64	NS	0.63	NS	4.36	3.58
Morris JF	09	4.241 - 0.025A + 0.148H in	-1.260 - 0.032A + 0.092H in	0.42	0.74	0.53	0.55	4.66	3.62
Schmidt	10	-2.815 - 0.022 + 0.119H in	-897 - 0.031a + 0.085 + 85H in	0.73	461	0.69	0.80	4.26	3.55

A = Age (years); H = Standing height; in = inches; cm = centimetres; m = metres; FVC = Forced vital capacity; FEV1 = Forced expiratory volume in 1 second; R² = correlation coefficient; SEE = Standard error or estimate; L = Litres; W = White; B = Black;

TABLE 2 (iii) (continued): PREDICTION EQUATIONS (SPIROMETRY) FOR ADULT MALES

AUTHOR		REGRESSION (PREDICTION) EQUATION		STATISTICAL TESTING		PREDICTED NORMAL	
NAME	NO.	FVC (WHITE) FVC (BLACK)	FEV1 (WHITE) FEV1 (BLACK)	R ² SEE	FVC SEE	R ² SEE	40 YRS/170 CM (L) FVC (W) FEV1 (W) FVC (B) FEV1 (B)
Schoenberg	11	-4.91 + 0.00057HW + 1.9461nA -0.0009916AW - 0.000356W ²	-0.05296 + 0.000639HW + 0.74661nA - 0.06385W - 0.0001608W ² - 0.0000313AHW	0.56 0.60	0.64 0.44	0.64 0.44	4.51 3.48
		-18.07 + 0.05496H + 3.58881nW - 0.000212A ² + 0.0002163HW	-8.407 + 0.06692H + 0.1826A -0.0009733AH - 0.0004025A ²	0.38 0.52	0.49 0.42	0.49 0.42	3.62 2.93

A = Age (years); H = Standing height; in = inches; cm = centimetres; m = metres; FVC = Forced vital capacity; FEV1 = Forced expiratory volume in 1 second; R² = correlation coefficient; SEE = Standard error or estimate; L = Litres; W = White; B = Black;

TABLE 2 (iv): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR ADULT MALES HAVE BEEN DERIVED: INVESTIGATIONAL TECHNIQUE

AUTHOR	REGRESSION COEFFICIENTS			RACE vs SOCIO-ECONOMIC STATUS				STATISTICAL METHODOLOGY
	NAME	NO.	HEIGHT AGE OTHER	RACE	SOCIO-ECONOMIC INFLUENCE ANALYSED	DISCUSSED	RELATIVE INFLUENCE ANALYSED	
Bass H	01	St H A	W/BSA	American White	No	No	No	NS
Black	02	St H A	-	American White	No	No	No	Multiple regression Analysis of co-variance
Crapo	03	St H A	W/BSA/H ² /H ³ /H	American White	No	No	No	Multiple regression Strato t/test
Cherniack	04	St H A	W	American White	No	No	No	NS
Dockery	05	St H A	W/H ² /A ²	American White	No	No	No	Least squares regression 2 way analysis of variance
Ferris	06	St H A	-	American White	Yes - occup/area live with (re: LFT's) resp. symptoms	Dismissed	No	NS
Knudson	07	St H A Sit H	W	American White	No	Dismissed	No	Multiple regression Correlation analysis

St H = Standing height; A = Age; W = Weight; BSA = Body surface area; Chest circ = Chest circumference; Cigs = Cigarettes

TABLE 2 (iv) (continued): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR ADULT MALES HAVE BEEN DERIVED: INVESTIGATIONAL TECHNIQUE

NAME	AUTHOR	REGRESSION COEFFICIENTS			RACE vs SOCIO-ECONOMIC STATUS			STATISTICAL METHODOLOGY	
		HEIGHT	AGE	OTHER	RACE	SOCIO-ECONOMIC INFLUENCE ANALYSED	DISCUSSED		RELATIVE INFLUENCE ANALYSED
Kory	08	St H	A	Chest circ/BSA	American White	No	No	No	Product moment correlation
Morris JF	09	St H	A	-	American White	No	No	No	Multiple regression
Ferris BG	09a	St H	A	Cigs	American White	No	Yes - resp symptoms	No	NS

St H = Standing height; A = Age; W = Weight; BSA = Body surface area; Chest circ = Chest circumference; Cigs = Cigarettes

effort, are also presented. These studies have all contributed tremendously to the understanding and fallacies of the current status of pulmonary function testing.

1. **Schmidt**^{66,154}

This study is included because the equations were recommended by the Intermountain Thoracic Society¹⁵⁵. The prediction equations were based on data combined from two different studies. Eight hundred and twenty men were included in this combined group, with a mean age of 48.6 years (standard deviation 18.6). Although the methodology and equipment were the same, the combination of data compromises the use of these equations. Another possible limitation of this study is the use of an extremely narrow population base of highly specific ethnicity. The reliance on volunteers in both studies (social club members in the latter and blood donors in the earlier studies) further adversely affect the applicability of the results to a general population. The interpretation of the results is further compromised by the use of data from a population of varying smoking habits. Other potential errors arise from the use of the Kory technique²¹ in calculating FEV₁ which begins the measurement of time and volume at the point at which 200 ml have been expired. The basis for this was to get past the initial part of the curve where flow may be submaximal. This tends to underestimate these values and is not accepted by the American Thoracic Society⁵¹.

2. **Morris**^{64,65,156}

Morris's values are widely used in the United States and South Africa. They were recommended by the American College of Chest Physicians⁴⁷ (ACCP) and the American Thoracic Society in 1977 in its handbook "Chronic Obstructive Lung Disease". The data was re-analysed by Miller¹⁵⁷ and the regression equation confirmed. Normality was rigidly defined as current non-smokers and absence of respiratory diseases by completion of a questionnaire. No attempt was made, however, to exclude heart disease and radiographic (and clinical) examinations were not performed. Subjects were recruited during the Respiratory Disease Association survey, but the method of selection is not obvious. The

acceptability and reproducibility of the functions are unknown as no more than 2 efforts were obtained from an unknown number of subjects. The largest of the attempts was chosen, but criteria for ensuring acceptability of the traces is also not clear. Subjects came from an extremely narrow-based, religious community in whom smoking was forbidden. This raises the question of whether they are fully applicable to various urban populations and subjects of other national origin.

Lastly, the Kory method was used for calculation of FEV_1 . This results in a smaller value than obtained in the currently recommended method, back extrapolation. As a consequence there are practical problems in using these normal values. Not only are they inconsistent with the recommended method of obtaining FEV_1 , but as a result provide predicted values for FEV_1 and FEV_1/FVC ratio which are systematically too low and thus may mask impairment in subjects who are tested according to current specifications.

3. Crapo⁷¹

This major study is important as the investigator's objective was to establish normal values using standards that meet ATS recommendations. The 1987 American Thoracic Society statement⁵⁴ on evaluation of impairment/disability secondary to respiratory disease and the Intermountain Thoracic Society manual⁵² recommended the regression equation derived from this study (for FVC, FEV_1 , FEV3, FEF 25-75%, FEV_1/FVC , FEV3/FVC). This study is well described with clear methodology and analysis techniques stated. The population studied were urban dwellers (Salt Lake City), of whom more than 90% were Mormons. The screening for "normal" subjects was comprehensive and included a negative respiratory symptom questionnaire, normal clinical and radiological examination and lifelong never-smoker (less than 0.5 packs/year). The major limitations in this study include the small number of subjects, their narrow geographic and ethnic distribution, and the use of volunteers. Although the investigators validated their equipment according to ATS specifications, Glindmeyer has raised the question as to whether this was in fact achieved⁵⁹. The group was of single ethnicity and probable socio-economic class so that the study could not address the influence of these factors on lung function.

Of interest is the fact that this study gave similar results to the aforementioned study by Morris and colleagues (once their values for FEV₁ are calculated by the back extrapolation method)¹⁵⁸. The latter group studied a population of similar ethnic background but at different altitude and rural, rather than urban, dwellers. The similarity of functions for similar populations living in rural or urban areas, as well as different altitudes is of particular interest to the present study.

4. Higgins^{67,159}

This study of a large number of subjects, 6365 subjects \geq or equal to 10 years of age (2320 of whom were \geq or equal to 20 years of age) made a good effort to derive data representative of a diverse local community. The sampling methodology was well planned and executed. Only two spirometric tracings were obtained and the best effort was defined with the largest FVC. Reproducibility and acceptability of lung functions performed in this way cannot be demonstrated and this greatly reduces the value of this study. The duration of the study allowed the collection of useful longitudinal data.

5. Knudson^{58,60}

The pulmonary function indices for all age groups and longitudinal data derived from this study are widely quoted. In South Africa the prediction equations presented in the most recent analysis (published in 1983) are widely used in clinical laboratories. The study is also recommended by the National Institute of Occupation Health (NIOH) (USA)¹⁶⁰ and World Health Organisation Study Group (WHO) on Selected Vegetable Dusts for use in populations of European descent¹⁶¹. Knudson attempted to survey a representative sample of a diverse, but localised, geographic community. The selection of the study population has several problems. Tucson, in the Arizona desert, has attracted several generations of patients with respiratory and allergic disorders. It has a mixed population comprised of white Americans and Mexicans, of whom only whites were included in the survey. The sampling technique adopted and the use of only the healthiest segment of the population may introduce bias. These factors may result in the data not being representative of the typical American population. The small number of men between the ages 25-85 years (only 86 men) makes the data particularly weak in the age group of greatest

importance in occupational medicine. Despite this fact these equations were adopted by the United States government agencies as reference values for disability valuations of coal and cotton workers.

The values for FVC derived in this study were smaller than those of most other investigators. In addition the values of Vmax50 and Vmax75 were greater than those observed by other workers. These differences were most likely due to inadequate expirations and the derivations of flows from a composite curve. Knudson and co-workers recognized these difficulties and re-analysed their work.⁶⁰ Following the ATS recommendations, the FVC and FEV₁ were taken from the single best value and flows from the test with the largest sum of FEV₁ and FVC. Effort was evaluated by the MEVF curve and a few subjects were rejected. This latter re-evaluation is probably the most significant factor contributing to the new values demonstrated. The new regressions for FVC and FEV₁ were larger and the flow considerably smaller and steeper. This re-analysis has provided excellent information on the growth maturation and decay of pulmonary function; but the problems resultant from population selection remain.

6. Dockery et al^{110,162}

The prediction equations generated by Dockery were based on a large sample of United States citizens. The samples were randomly selected from different census lists in six varied communities, including Portage, Topetia, St Louis, Stuebenville, Kingston-Harrison and Watertown. Of the total adult (25-74 years of age) population selected (11,040), 2454 white never-smokers with no respiratory symptoms were studied, one quarter of whom were male. The study was conducted as part of a longitudinal study of the respiratory effects of air pollution. The population was therefore carefully screened for respiratory illness. Only lifetime non-smokers were included, but, again, the precise definition of a smoker is not clear. The age group 25-74 years of age ensured that only mature lungs were studied. The testing methodology, however, did not meet ATS standards. The final equations utilized exponentials of height (height²) and age (age²) as coefficients. As a guideline, the authors indicated that a value reported as FVC or FEV₁/Ht(m)² can be multiplied by 3m² to arrive at the equivalent value in L. There is, however,

no good evidence to support the use of exponentials as has been discussed in Chapter 1, page 11. The authors argue that linear equations do not fit the data and that the R^2 is greatly improved by including exponentials in the model. The data does, however, fit linear models when these are applied, with R^2 values similar to other investigations and not very different from those obtained with the more complex approach.

The investigators also examined the pulmonary functions of asymptomatic black never-smokers. The exact number in this group is not clear, but 242 blacks were present in the initial group tested. They found that the height standardised values for FEV_1 and FVC were approximately 13,5% lower than those for whites of the same sex. These findings were similar to the 12,5% inter-racial difference found among black children in the same study. It is not possible to comment further on these findings as a clearer definition of this "black" population and information concerning their socio-economic environmental status and smoking habits is not provided.

7. Miller and Thornton¹⁶³

These recently published, "normal values" are widely held to be representative of the general population of the United States. The subjects were drawn from the entire state of Michigan (population 9 000000). A stratified cross sample was selected from the entire state including the metropolitan area, smaller cities, industrial towns, farmland and isolated communities. The exact ethnic constitution was not precisely defined, but the white subjects were of diverse national origin. Flow volume loops, generated from a rolling seal spirometer were used to measure lung functions, including FVC, FEV_1 and MMF. The best of 3 efforts was analysed provided the values for FEV_1 and FVC agreed within 5%. Smokers were included in the analysis. This detracts from the otherwise excellent methodology. The failure to examine the influence on socio-economic and ethnic factors is also disappointing.

8. National Health Examination Survey¹⁶⁴

The National Centre for Health Statistics attempted to conduct a survey intended to be representative of the entire United States. The study, recently reviewed by Miller⁷⁵, was apparently conducted in 3 phases (cycles I - III). Cycle I did not include pulmonary function testing and the data for Cycle II have not been published. Cycle II recruited 7417 children between the ages of 6 and 11 years of age. Clinical examinations, including respiratory symptom questioning was conducted on the vast majority (96%). A highly stratified multi-stage probability analysis was used to group the population into superstrata, which were homogeneous with regard to urbanisation and industrialisation. Spirometry was then performed on selected clusters and sub-clusters based on their proportion of the total population. This is of particular concern as the details regarding the subjects that were tested and the handling of selected subjects who did not complete the survey is not detailed. Miller points out that the quality of the population sampling was of acceptable standard, but that this cannot be said for the quality of the spirometric testing. Several inexperienced, poorly trained and poorly supervised technologists were, apparently, used. Spirometry was performed using a water-sealed spirometer, the exact features of which are not clear. The calibration checks for accuracy and precision are also not clear. The usefulness of the spirometry obtained is further reduced by the performance of only 2 spirograms on most subjects: during this study 3000 spirograms had to be remeasured and/or alternate trials substituted. At the final analysis spirometric data was available for only 18.5% of the subjects; only FVC was thought to be of any value, while the data for FEV₁ and FEF 25-75% were discarded. Although the results for FVC were presented, the Public Health Service did not recommend them for use as clinical standards. The study is, however, reviewed here as it does provide information on the development of FVC in children and because the data suggest that the difference between black and white children can be halved by using sitting rather than standing heights. This conclusion is difficult to accept in the light of the above discussed problems.

The survey has been continued as the Health and Nutrition Examination Survey (HANES) since 1971. During the period 1971 to 1975 a sample of 5544 adults 25-74 years of age, underwent pulmonary function testing. A computerised rolling seal spirometer was used. The actual distribution of ages is not

well presented. This survey aimed to provide information for a general population. No attempt was made to exclude subjects with respiratory symptoms or a past or current history of chest illness. Thus Miller suggests that it is possible that in all or some of the sub-groups the mean values would be lower than expected. Although this was apparently acknowledged by the investigators, the prevalence of such "abnormal" subjects was not stated and, therefore, prediction equations for normal subjects cannot be generated. This detracts from the use of this data for the purposes of investigating normal lung function. The methodology for pulmonary function testing was also poor and did not meet ATS requirements. Inexperienced technologists were used. Reproducible tracings were obtained in 92% white males, but only 82% white females, 81% black males and 60% black females. This suggests poor technologist technique. Reproducibility was defined as within a 5% range for FVC and FEV₁, but was within 10% if values were less than 3 litres. No information concerning the acceptability of the trace was described. It is also disappointing that such a large, well-planned study failed to examine the role of socio-economic and environmental factors on spirometry.

9. Schoenberg and Beck^{61,63}

The "normal values" determined by these investigators are commonly used in clinical laboratories, including our own. They studied a diverse general population, including blacks, who lived in 3 varied communities in eastern United States: urban Ansonia, Connecticut and semi-rural Winnsboro, South Carolina and rural Lebanon, Connecticut. In total, flow volume curves were recorded on 3046 asymptomatic individuals. The investigators found that simple linear regressions did not fit the data obtained, overpredicting at each end of the range and underpredicting in the middle. More complex models utilizing weight as well as multiples and exponentials of height and age were developed. The published equations are therefore not comparable with the linear regressions generally reported for spirometric measurements.

There are several problems that arise from these studies. Despite careful sampling and follow-up, only 64% of all residents ≥ 7 years of age were tested. Of the 3046 individuals tested there were 581 white

and 241 black adult females, but only 194 white and 120 black adult males. The definition of adult (defined as ≥ 15 years of age for females and ≥ 18 years of age for males) resulted in a large proportion of "still growing" lungs being included. The proposed definition of normal, asymptomatic non-smokers did not clarify the extent to which previous smokers were studied and did not include radiographic examinations. In addition, current smokers were included in the black male group. In the analysis of lung functions the two tests (out of five) with the largest FEV₁ were averaged provided they agreed within 10%. This methodology does not conform with ATS standards and the authors do not state in how many instances the two best tests did not agree with each other. These criticisms may partially explain the poor fit of their linear regressions. Further, no attempt was made to investigate the socio-economic and environmental background of the population studied.

10. Bass¹⁰⁸

This study, performed in Boston, USA and published in 1973, is worthy of mention as it was designed to provide normal values for specific indices calculated from the then recently introduced flow-volume loop. The methodology was poor and did not conform to current standards. The population was not well defined and in any case was composed of volunteers, so detracting from the study. Additional problems with the study design were the inclusion of anyone who smoked less than 1 pkt/day for 5 years as "non-smokers" and an imprecise description of what constituted an adverse respiratory status in the screening process. The lung function testing methodology was also poor with only 2 blows being recorded and no clear information being given as to what was regarded as an unreliable trace (other than a subjective comparison of the standards). The study did, however, demonstrate the differences between normal flow volume patterns as compared to those of obstructed airways pathology and helped to establish the test in the clinical laboratory.

11. Cherniack¹¹¹

The prediction equations presented by Cherniack were based on a population of never-smokers living in an "essentially pollution-free area", free of any significant chronic respiratory symptoms. The precise

definitions of what constitutes a "smoker", "pollution" or "chronic", is not given and this detracts from the study. The definition of the population and how they were selected are also not given, so further detracting from the usefulness of the study. The number of subjects in the 20-30 year age group (the largest age group in the study) under 25 years is not stated. This detracts greatly from the study as the number of "still growing" lungs was presumably large. The use of a new piece of equipment which had been developed especially for the survey, was a gamble. Although it appears to have stood up to the rigours of an epidemiological survey its functioning does not appear to meet current ATS standards. Nevertheless, this study does provide important data on a healthy population not exposed to many adverse respiratory health factors. Prior to the standardisation of lung function testing by the ATS, these reported values were amongst the most highly regarded.

12. Predicted Values in Europe

For completeness, the major prediction equations used in Europe will be reviewed briefly. These have been well reviewed by Arcangeli¹⁶⁴ and by Cotes.¹⁴² Studies on several populations in Europe, Great Britain and North America have demonstrated similar regression equations.¹⁶⁵ It is noteworthy that measurement of "vital capacity" in continental Europe is performed as an inspiratory VC, as opposed to Great Britain and North America where "vital capacity" is an expiratory VC. It has been demonstrated that the correlation between expiratory and inspiratory vital capacities is almost perfect with the difference being in the region of no more than 180 ml (inspiratory VC greater) in normal subjects, although a much larger difference may be demonstrated in patients with pulmonary disease.¹⁶⁶

Several locally derived prediction equations are widely used in clinical testing in Europe. In general, the studies do not conform to the rigid standards laid down by the American Thoracic Society and are not widely used in South Africa. Two of the most frequently quoted studies, by Cotes^{159,165} and Berglund,¹⁶⁷ were in fact performed more than twenty years ago. The methodology and equipment used has long been changed and the studies are mentioned only for completeness' sake. Two important recent studies are those of Fredriksson¹⁶⁸ and Viljanen.¹⁶⁹ Fredriksson studied 263 volunteers (all

males) in the Uppsala County of Sweden. The population screening and performance of lung function tests does not conform to ATS standards. Regression equations (including smoking variables) were, however, provided for FVC and FEV₁, as well as for a number of other pulmonary function tests. Viljanen studied 553 subjects (including 296 males) who were normal, non-smoking workers in Helsinki. The method of selection and precise nature of their work is not clear, so detracting greatly from the value of these prediction equations. It is of interest that the suggested normal values for FVC are lower than those predicted for whites in those studies performed in North America. Such differences may be the result of race or, more correctly, population group differences. Thus, highlighting the difficulties inherent in generalising rare specific reference values for different population groups within the same race.

Normal values produced by the ambitious European Coal and Steel Community study have been widely used to assess industrial populations in Europe.⁴⁹ The values are based on the combination of two separate projects. The main project tested 3153 normal male workers 18-65 years of age in the coal and steel industries of the six nations that then comprised the European Economic Community. The values are not representative of a normal population as they are influenced by the inclusion of smokers and, in the opposite direction, by the "healthy worker" bias. The methodology used also does not meet the currently accepted standards for instrumentation, testing methodology and analysis. A supplementary project, testing male 66-80 years of age and women was subsequently added. Recognising the pitfalls of these values, the working party on standardisation of lung function tests of the European Community for Coal and Steel suggested the use of summary equations.⁴⁹ These were pooled together from studies by various investigators in both America and Europe. The summary equations are means of the individual regression equations after standardizing for only the independent variables age and height. These values may be useful for screening epidemiologic studies. They are not suitable for evaluation of individual subjects in occupational medicine or general clinical use because of the following limitations: they failed to weight the series by the number of subjects and to evaluate them for consistency, acceptability and reproducibility of the spirometry obtained for the consistency of smoking status and other sources of measurement and subject variation.¹⁷⁰

It is therefore evident that there have been many attempts to quantitate normal spirometric values. Despite attempts to improve their accuracy, it is not possible to identify a set of normal values that is neither subject to sources of error, nor unquestionably representative of the general world population. Despite these shortcomings very important conclusions have been drawn as to the observation that whites have larger spirometric values than blacks. In the next chapter, the studies that investigate lung function in blacks will be considered and their relationship to the major prediction studies discussed.

2.3 SELECTED MAJOR PREDICTION STUDIES AND THEIR REFERENCE VALUES FOR TLC_{SB} AND DL/VA

A review of the major studies giving rise to prediction equations for single gas transfer is now presented. The confusion that abounds with prediction equations for spirometry is only surpassed by the confusion regarding normal values for single breath diffusing capacity. Only the major studies which have attempted to use currently accepted standardised methodology are reviewed in detail. These predictions are summarized in Table 2 (v) - 2 (vii). The values of Crapo¹²² and Morris¹⁵¹ have been recommended for the evaluation of respiratory disability⁶¹.

1. Important studies not producing generally accepted prediction equations

These studies have had an important influence on the use of transfer factor and the evaluation of predicted normals. Ogilvie²⁸ described one of the most commonly used test methods but his prediction equations are based on only 25 subjects whose smoking histories were not obtained. McGrath and Thompson studied only 33 adults males whose smoking histories were not considered¹⁷². He predicted normal values for men and women and these values have been widely adopted for both sexes. Burrows¹³⁰ studied 135 hospitalized patients. The authors attempted to exclude respiratory impairment, although they did include 69 subjects who "had insignificant or localised pulmonary lesions". Anderson¹⁷³ studied 43 men, only 11 of whom were non-smokers. Gaensler studied 98 normal subjects who were employees at a tuberculosis hospital. Two thirds of males and one half of the females were smokers. Ayers¹³¹ population consisted of 61 normal adults. Samet¹⁷⁴ studied 140 healthy male

TABLE 2 (Y): MAJOR STUDIES FROM WHICH PREDICTION EQUATIONS (TLCO_{5B}S) FOR ADULT MALES HAVE BEEN DERIVED

AUTHOR NAME REF	AUTHOR NO.	LOCATION		POPULATION										NORMALITY SCREEN								
		SITE/ (ALTITUDE)	YEAR PUB	TOTAL N	BLACK MALES N	WHITE MALES N	POP. BASE U/R	W/B C/B S/B	SELECTION CRITERIA	AGE MEAN (RANGE)	> 25 - < 65 YRS N	DATA NON- ATTENDERS	CXR PA/L FS/M	QUEST. I/V TECH.	OCCUP. HISTORY	SMOKING STATUS	CLIN. EXAM	NORMAL POPULATION (DEFINITION)				
Crapo 122	01	Salt Lake USA (1400)	1981	314 M+F (245)	-	NS (123)	NS	NS	NS	NS	NS	48.5 +20 (15-91)	NS	NS	Yes PA/L	MRC Mod	Self	NS	Yes Never	Yes	Yes	< 0.5 pkt/year - non < 6 months No heart/Lung/chest disease No current cardioresp. symptoms Normal examination Normal CXR FEV1/FVC% >0.70
Knudson 29	02	Tucson Arizona (700 ft)	1987	1421 (228)	-	NS (99)	U	C/B	Stratified random cluster sample	NS (7-90)	71	NS	NS	NS	NS	NS	Self	NS	Yes	NS	NS	Denied regular smoking No Asthma/heart trouble /chest/emphysema/ chronic bronchitis bronchiectasis No dyspnoea on exertion SOB/wheeze/tightness No CVA Neuro muscular

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based; CXR = Chest radiograph;
 PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 2 (V) (continued): MAJOR STUDIES FROM WHICH PREDICTION EQUATIONS (TLCO_{SGS}) FOR ADULT MALES HAVE BEEN DERIVED

AUTHOR		LOCATION		POPULATION				NORMALITY SCREEN													
NAME REF	NO.	SITE/ (ALTITUDE)	YEAR PUB	TOTAL N	BLACK MALES N	WHITE MALES N	POP. BASE U/R	SELECTION W/B C/B S/B	CRITERIA	AGE MEAN (RANGE)	> 25 - < 65 YRS N	DATA NON-ATTENDERS	CXR PA/L FS/M	QUEST. I/V TECH.	NS	ATNurses (med)	NS	OCCUP. HISTORY	SHOKING STATUS	CLIN. EXAM	NORMAL POPULATION (DEFINITION)
Miller 123	03	Michigan USA (1400)	1983	2542 (292 clear)	-	NS (249)	U+R	C/B stratified random sample	43	NS	NS (16)	Partial	Yes PA/L	NS	NS	Yes Separated	Yes	Yes	Yes	Yes	No sputum > 3months No dyspnoea (usually peer group)/wheeze (most days) or attacks of SOB and wheezing No angina pectoris No Chronic bronchitis /emphysema/TB/ pneumoconiosis Diastolic < 100 mmHg No clinical evidence of respiratory disease
Paoletti 124	04	Venice Italy (Sea level)	1985	3300 M+F 2688 tests 801 normal (712)	-	NS (243)	U+R	C/B Multi-stage stratified geographic cluster	±34 (8-64)	NS (80)	NS	NS	NS	NS	NS	Yes (med)	NS	NS	Yes Non	NS	Absence cardiopulm disease/BP/occup Non-smokers Normal spirometry

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based; CXR = Chest radiograph; PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 2 (V) (continued): MAJOR STUDIES FROM WHICH PREDICTION EQUATIONS (TLCOS_{BS}) FOR ADULT MALES HAVE BEEN DERIVED

AUTHOR	LOCATION	POPULATION	NORMALITY SCREEN													
NAME REF	SITE/ (ALTITUDE)	YEAR PUB	TOTAL N	BLACK MALES N	WHITE MALES N	POP. BASE U/R	SELECTION W/B C/B S/B	AGE MEAN (RANGE)	> 25 - < 65 YRS N	DATA NON- ATTENDERS	CXR PA/L FS/M	QUEST. I/V TECH.	OCCUP. HISTORY	SMOKING STATUS	CLIN. EXAM	NORMAL POPULATION (DEFINITION)
Van Ganse 124	Berlin New Hampshire USA	1971	203 (142)	-	(NS) (70) 16	U	Random subsample of random sample	52.3 ±13 (25->79)	16	NS	NS	NS	NS	NS	Yes mixed	NS

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based; CXR = Chest radiograph;
 PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 2 (vi): STUDIES FROM WHICH PREDICTION EQUATIONS (TLCO_{SB}) FOR ADULT MALES HAVE BEEN DERIVED: TESTING METHODOLOGY

TESTING METHODOLOGY																			
AUTHOR	NAME	NO.	VOLUMES	CO ANAL	HE ANAL	M/A	BHT(s) (RANGE) (METHOD)	VI % FVC (METHOD)	W/O VOL (L)	SAMPLE VOL (L)	NO. TESTS	INTERVAL BETWEEN TESTS	TEST SELECTION METHOD	CALCULATION [GAS] Co/ He/ O ₂ %	OTHER CORRECTIONS	VC MEASUREMENT	HB	[CO] TECH	
Crapo	01	NS	Infra-red (alinear)	NS	NS	NS	10 (NS) Ogilvie	NS (ITS)	NS	NS	2	NS	ITS modified Ogilvie	0.3 10 25	ATPD -->BTPS	NS	ALL	ALL NS	
Knudson	02	Collins water-sealed Stead Wells Spirometer	Infra-red	Thermal conduct (5 valve)	A	NS	10 9-11 ESP	90	1/ 0.5	NS	2	4 mins	Ave 10% < 3 ml	ESP	0.3 10 21	NS (3 trials)	Best FVC	ALL NS NS	
Miller	03	Fleisch Pneumotach	Electro-chem	Katho-rometer	NS	NS	10 8-12 Ogilvie	NS	1/ 0.6	NS	2 min	NS	Ave 10% < 3 ml	Ogilvie	0.3 10 NS	CO ₂ Abs	NS	ALL	No NS

NS = Not stated; Co Anal = Carbon monoxide analyser; He Anal = Helium analyser; M/A = Manual/Automatic; BHT (s) = Breath hold time (seconds); VI = Inspiratory volume; W/O = Washout volume; L = Litres; min = Minutes; Ave = Average; EP = Epidemiology standardisation technique; CO = Carbon monoxide; He = Helium; O₂ = Oxygen; [Gas] = Gas concentrations test mixture; VC = Vital capacity; HB = Haemoglobin; [Co] = Carboxyhaemoglobin estimation

TABLE 2 (vi) (continued): STUDIES FROM WHICH PREDICTION EQUATIONS (TLCO₅₀) FOR ADULT MALES HAVE BEEN DERIVED: TESTING METHODOLOGY

TESTING METHODOLOGY																			
AUTHOR	NAME NO.	VOLUMES	CO ANAL HE ANAL	M/A	BHT(s) (RANGE) % FVC (METHOD)	VI	W/O VOL (L)	SAMPLE VOL (L)	NO. TESTS BETWEEN TESTS	INTERVAL	TEST SELECTION	CALCULATION METHOD	[GAS] OTHER CORRECTIONS	VC MEASUREMENT	HB	[CO] TECH			
Paoletti 04		Fleisch No 2 Pneumotach	Electro-chem	Thermal conduct	A	10 <13 ESP	85	1/ 0.5	1	2-4	NS	Best < 5%	Ogilvie	0.3 10 20	STPD	NS	Yes	Nurses	
Van Ganse 05		Mark 11 Resparameter	Infra-red	Thermal conduct	NS	10 (7-13) Ogilvie	VC -0.3 L	NS	NS	2	NS	NS	Ogilvie	0.3 14 21 & 86	STPD	FVC 5 Trial	NS	No	NS

NS = Not stated; Co Anal = Carbon monoxide analyser; He Anal = Helium analyser; M/A = Manual/Automatic; BHT (s) = Breath hold time (seconds); VI = Inspiratory volume; W/O = Washout volume; L = Litres; min = Minutes; Ave = Average; EP = Epidemiology standardisation technique; CO = Carbon monoxide; He = Helium; O2 = Oxygen; [Gas] = Gas concentrations test mixture; VC = Vital capacity; Hb = Haemoglobin; [Co] = Carboxyhaemoglobin estimation

TABLE 2 (vii): PREDICTION EQUATIONS (TLCOSB) FOR ADULT MALES

AUTHOR		REGRESSION (PREDICTION) EQUATIONS		STATISTICAL TESTING		PREDICTED NORMAL		
NAME	NO.	TLCOSB (WHITE) TLCOSB (BLACK)	DL/VA (WHITE) DL/VA (BLACK)	R ²	TLCOSB SEE	R ²	SEE	
Crapo	01	0.410H - 0.210A - 26.31	7.08 - 0.034A	0.61	4.83	0.40	0.84	40 YRS/170 CM (L) TLCOSB (W) DL/VA (W) TLCOSB (B) DL/VA (B)
Knudson	02	-11.3527 - 0.2741A + 0.3551H	1.6164 - 0.0419A - 0.0235H	0.67	4.72	0.80	0.47	38.06
Miller	03	12.9113 - 0.229A + 0.418H	-	0.46	4.84	-	-	40.43
Paoletti	04	-31.3822 - 0.1936A + 0.4410H	-	0.57	NS	-	-	35.85
Van Ganse	05	9.711 - 0.202A + 16.36H m - 0.42LP	8.343 - 0.026A - 0.9H m - 0.06 LP	0.79	3.82	0.52	1.07	29.44

A = Age (years); H = Standing height; FVC = Forced vital capacity; FEV1 = Forced expiratory volume in 1 second; R² = correlation coefficient; SEE = Standard error or estimate; L = Litres; W = White; B = Black; LP = Lifetime packs/1000.

TABLE 2 (viii): STUDIES FROM WHICH PREDICTION EQUATIONS (TLCO_{SB}) HAVE BEEN DERIVED FOR ADULT MALES: INVESTIGATIONAL TECHNIQUE

AUTHOR	REGRESSION COEFFICIENTS			RACE vs SOCIO-ECONOMIC STATUS			STATISTICAL METHODOLOGY
	NAME	NO.	HEIGHT AGE OTHER	RACE	SOCIO-ECONOMIC DISCUSSED	RELATIVE INFLUENCE ANALYSED	
Crapo	01	St H A	W/BSA/Hb/ transformations Y ² , X, X ² , X, X ³	Mormon	No	No	Single and multiple linear regression
Knudson	02	St H A		American White	No	No	SPSS - Multiple regression
Miller	03	St H A	W/BSA/Hb/smoking factors	White participants	No	No	Univariate/frequency procedures SAS Multiple linear regression
Paoletti	04	St H A		Italian Rural	No	No	SPSS - Multiple regression
Van Ganse	05	St H A		White American	No	No	Multiple linear regression

St H = Standing height; A = Age; W = Weight; BSA = Body surface area; Chest circ = Chest circumference; Cigs = Cigarettes

industrial workers who were employed at sites where asbestos was used. Although they were not directly exposed to it they may have incurred sub-clinical effects. Their smoking status was also not considered.

2. Crapo¹²²

Crapo tested 245 normal subjects who belonged to the Church of Jesus Christ of Latter Day Saints and resided in the Salt Lake City area, at an altitude of 1400 metres. The population was rigorously screened to select a group of disease-free non-smokers whose FEV₁/FVC ratio was greater than 0.70. The use of volunteers from such a highly selected population may detract from the usefulness of this study as these individuals may have had particular reasons for participating in the study and, so introduce a source of bias. The well accepted, ITS recommended, modified, standardised, Ogilvie technique was used. It is however important to note that the modifications include the percentage of inspired oxygen being increased to 25% in an attempt to establish an alveolar PO₂ close to that seen at sea level. VA was measured using the single breath helium (He) method. The study is also important in its specific validation by this technique of the ITS modification. The values predicted by Crapo are amongst the highest reported. This may be explained by the following; the inspired gas (volume V₁) was regarded as dry (ATPD) in contrast to the technique reported by others which assumes V₁ to be saturated with water (ATPS)⁵⁵. Assuming V₁ to be at ATPS and not ATPD will result in a TLCO 3-4% lower than if the latter is accepted. The second possibility was the performance of the test at high altitude (1400 m). The use, however, of the 25% oxygen test gas and the demonstration of an average alveolar PO₂ of 1200 mm Hg (similar to that reported at sea level) makes this an unlikely explanation. The extensive selection of the population, together with the use of ATPD, are the most likely explanations for these relatively high predicted values. The normal values produced in this study are recommended by the ITS⁵² for use by laboratories and by the ATS⁵⁴ for evaluation of respiratory disability.

3. Knudson²⁹

This study was incorporated in the final phase of the longitudinal study of the inhabitants of Tucson, Arizona. The relevant methodological criticisms have been discussed in the previous section. Of 1421 subjects (older than 7 years) who underwent spirometric testing including single breath, only 228 subjects met the final criteria for analysis, being healthy non-smokers with acceptable and reproducible TLC_{CO_{SB}} traces. This may have introduced a bias into the final sample analysed. Only 71 of these subjects were in the group > 25 years. The study adhered to the ATS-sponsored Epidemiology Standardisation Project⁴⁵ criteria. This makes them difficult to compare with other studies but it is of interest that they compare fairly well with those of Crapo and Morris¹²².

4. Miller¹²³

The prediction equations generated by Miller are based on one of the largest studies (511 subjects with normal haemoglobins and 204 non-smokers). Most subjects lived at sea level, the highest altitude was 300 metres. The population that was studied included a wide range of nationality, residence, occupation and socio-economic factors, so making them perhaps the most representative of a general population. The selection methodology was excellent with a good response rate of selected individuals. The set of equations that were generated takes into account the effect of cigarette smoking. The study utilized a demand-valve system and an electrochemical CO sensor. Although they validated the use of these techniques, the demand valve system may have introduced systematic error. They indicated the need for smoking-specific equations for use in surveys where the population served contains a large number of smokers. Equations for current smokers and for male ex-smokers were lower in level than those for non-smokers. The Michigan equations are derived from a broad general population. They permit adjusting for the effects of cigarette smoking in otherwise normal subjects.

5. Paoletti¹²⁴

The regression equations presented by these authors were derived from data obtained in the first phase of a prospective longitudinal epidemiologic study of a general population. The aim of this study was to

evaluate the future long term effects of air pollution emanating from a large oil burning thermo-electric power plant which was to be established in the area. The selection of subjects using an acceptable statistical approach was methodical, although the determination of sample size using Knudson's approach to estimate prevalence rates of chronic respiratory disease may not have been applicable. The exact distribution of socio-economic class is not clear and its effect on lung function was not reported. This data appears to have been collected and perhaps will be analysed in the future. Despite an excellent turnout of those enrolled (94%), the inability of 20% of subjects correctly to perform single breath tests is disappointing. This is further highlighted by the presence of only 80 males in the age group >19 to < 64 years. The screening of "normality" was extensive, although the absence of a radiological screen in such an important longitudinal survey is disappointing. The investigators attempted to use the methodology prescribed by the ESP, but the analysis is weakened by the use of inspiratory volumes > 85% (compared with the ATS recommended 90% of the best FVC), wide tolerance of breath hold times (only excluding those > 13 secs) and the use of the highest value obtained. It is worth noting, however, that Knudson has suggested that the use of this lower cut off is in fact justified³¹. The investigators also do not state the time interval between successive tests. These factors, and the other technical differences highlighted in the table may explain the relatively high values obtained for single breath determinations in this study.

6. Van Ganse¹²⁰

Van Ganse studied a small number of individuals, including only 16 non-smoking adult males. The testing methodology does not conform to any of the currently accepted minimum standards. A major defect in the methodology employed was the use of only one test per subject. The study is, however, of interest because of its examination of the effect of smoking on gas transfer and the attempt to model a smoking variable in the prediction of normal values.

7. Conclusion

The values of Crapo and Morris¹²² have been recommended for the evaluation of respiratory

disability⁵⁴. However, as is apparent in Table 2 (vii), these values are significantly higher than virtually all others reported. Some subjects which may be classified as "low normal" using any other set of reference values will be reported as abnormal. Miller points out that 31% (male) normal non-smokers in his Michigan study would be classified as abnormal when the Crapo¹²² equations were used, compared with percentages less than 5% using the equation of Gaensler, van Ganse¹²⁰ or Miller¹²³. Thus work is still required in this field in order to produce generally accepted normal values. The role of nutrition and socio-economic factors on TLC_{SB} has not been evaluated by any research group.

2.4 NORMAL VALUES FOR TOTAL LUNG CAPACITY

The use of normal values for total lung function capacity has been compromised by the poor quality of predictive equations which are derived from small series using different methods, mixed smokers and non-smokers and the values that have been generated vary markedly. In this section only those studies using gas dilution techniques that have given rise to prediction equations used in South Africa are reviewed.

1. Goldman and Becklake¹⁷⁴

Many laboratories have utilized these predicted values and they are still used in most laboratories in South Africa. The results are unfortunately less than optimal. They are based on a small volunteer population of only 44 male and 50 female subjects, all of whom were "members of the hospital staff and their relatives". Although screened for "major respiratory or cardiac illness" it is not certain as to whether symptoms suggestive of cardiorespiratory disease such as frequent cough or occasional wheeze also led to exclusion. This may have led to the inclusion of individuals with mild, but significant, gas trapping and so resulted in Miller's observation that the residual volumes of healthy young adults are considerably smaller than those found in this study.¹⁶⁹ Tests were performed by a closed circuit method using hydrogen. The equipment used does not conform to currently accepted standards. The study is, however, one of the best attempts to establish normal values for total lung capacity to date.

TABLE 2 (ix): STUDIES FROM WHICH PREDICTION EQUATIONS (TLC: DILUTIONAL TECHNIQUE) FOR ADULT MALES HAVE BEEN DERIVED

AUTHOR		LOCATION		STUDY POPULATION							METHODOLOGY		
NAME REF	NO.	SITE	YEAR PUB	NO. OF ADULT SUBJECTS (No males) Mean (Age Yrs) (Range)	POP. BASE U/R W/B C/B S/B	SELECTION CRITERIA	DATA NON-ATTENDERS	SMOKING STATUS	NORMALITY SCREEN	DILUTION TECHNIQUE	ATS STANDARDS	BTPS CORRECTED	
Baldwin	01	USA	1948	52	U	H/B NS W/B NS S/B	NS	Mixed	NS	Open circuit Nitrogen	No	Yes	
Boren	02	USA	1966	422 (422) (NS) (38.5) (20-66)	U	W/B NS S/B	NS	Mixed	See Table 2 (1) Kory	Open circuit N2 + closed circuit He	No	Yes	
Goldman	03	Johannesburg SA	1959	44	U	W/B NS S/B	NS	Mixed	No major cardiac or respiratory illness	Closed circuit Hydrogen	No	Yes	

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based; CXR = Chest radiograph; PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 2 (ix) (continued): STUDIES FROM WHICH PREDICTION EQUATIONS (TLC: DILUTIONAL TECHNIQUE) FOR ADULT MALES HAVE BEEN

AUTHOR		LOCATION		STUDY POPULATION					METHODOLOGY			
NAME REF	NO.	SITE	YEAR PUB	NO. OF ADULT SUBJECTS (No males) Mean (Age yrs) (Range)	POP. BASE U/R W/B C/B S/B	SELECTION CRITERIA	DATA NON-ATTENDERS	SMOKING STATUS	NORMALITY SCREEN	DILUTION TECHNIQUE	ATS STANDARDS	BTPS CORRECTED
Needham	04	Scotland	1954	N4 (102) (NS)	W/B NS	NS	NS	Mixed	No asthma/frequent cough/ closed circuit/chest colds/ smokers cough/chest colds No dyspnoea No obesity Normal clinical and CXR examin.	NS	No	No

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based;
 CXR = Chest radiograph; PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 2 (X): PREDICATION EQUATIONS FOR TOTAL LUNG CAPACITY (GAS DILUTION METHOD) ADULT MALES

AUTHOR	REGRESSION EQUATIONS	STATISTICAL TESTING	PREDICTED NORMAL
NAME NO.	TLC (WHITE)	R ² TLC SEE	40 YRS/170 CM TLC (W) LITRES
Goldman 01	$-9.167 - 0.015A + 0.094H$	0.77 NS	6.21
Needham 02	$-4.21 - 0.01A + 0.16H_{in} + 1.5 BSAsqm$	NS 0.68	5.18
Baldwin 03	FVC x 1.31 (ages 35-49) FVC x 1.45 (ages 50-69)	NS NS	-
Boren 04	$-7.30 + 0.078H$ cm	0.56 0.87	5.96

A = Age (yrs); H = Standing height; BSA = Body surface area; TLC = Total lung capacity; R² = Correlation coefficient;
SEE = Standard error of estimate; FVC = Forced vital capacity; NS = Not stated

2. Boren¹⁷⁵

This is the largest series available. Total lung capacity determinations were made on a sample of participants (422 men) of the Veteran's Administration study of pulmonary function (see Kory, page ??). The choice of a hospital based population with its attendant source of bias and the lack of information regarding population selection detracts greatly from the study. The use of prediction equations derived from individuals of varying smoking habits further complicated the interpretation of the values obtained.

3. Needham¹⁷⁶

This is one of very few studies of total lung capacity performed in Europe. Adult participants were drawn from a wide range of occupations, but no information is presented regarding either the selection technique nor the degree to which the participants could be regarded as being representative of the general population. Only healthy people were included in the group analysed but the normality screen was not stringent and did not exclude current or previous smokers. Although the investigators argue that this was because of their aim to "sample" a cross-section of an ordinary, healthy, and not an exceptionally fit community, the interpretation of the results obtained and comparison with values obtained from other studies is difficult. The equipment used also does not conform to current standards.

4. Baldwin¹⁶

This is the earliest study whose prediction equations are still in use. Only 52 subjects were studied. No information is given regarding the selection of participants, nor their health status. Again, smokers were included. The testing methodology also did not meet currently accepted minimum standards.

2.4 CONCLUSION

It is obvious that many attempts have been made to investigate normal values for pulmonary functions. Over the years tremendous improvements have been made in standardising the methodology and equipment used. This has improved the quality of the data obtained. Standardisation has also highlighted the wide variation of lung function that exists despite the elimination of measurement

variation. It is therefore important that other methodological techniques be scrutinized particularly those relating to population selection and definition and the errors that may confound group comparative studies. The question of "race" differences have always resulted from such group comparative analyses and the demonstration that the outcome of regression modelling is improved by separation of the "race" groups. The potential sources of error that arise from such techniques are examined in the next chapter, which reviews the major studies investigating lung function in blacks.

CHAPTER 3

3. THE ROLE OF RACE IN DETERMINING LUNG FUNCTION

3.1 INTRODUCTION

The identification of race as a confounding variable is particularly important in an evaluation of the appropriateness of currently used pulmonary function reference values. Comparative African/European studies (dating back more than 100 years) both in Africa and in the New World have shown that lower spirometric volumes are observed among the African populations¹⁷⁷⁻¹⁹⁵. The observation that "blacks" have smaller lungs than "whites" was first made by Gould¹⁷⁷ in 1869; a mere 23 years after Hutchinson⁷ popularised the spirometer. He found that the vital capacities of "blacks" were "markedly inferior - by some 330 cc" than those of "whites" in his famous study of civil war soldiers. These differences were apparently present even when men of similar height and chest circumference were compared. Damon²⁰⁴, in his review of these early studies of "racial" differences in lung function, suggests that it was unlikely that the prevalence of early respiratory pathology was different between the two groups of soldiers and thus the observed differences were due to genetic differences.

Subsequent to Gould¹⁷⁷ study, several investigators have examined the question of racial differences in lung function during the first part of this century¹⁷⁸⁻¹⁸⁴. These studies were essentially designed to compare mean values in different groups and did not attempt to model normal functions using age or height variables. The important studies are listed in Figure 3 (i) below. A consistent finding in these studies was the demonstration of lower spirometric functions (FVC and FEV₁) in "blacks" compared with whites. These differences were found despite the fact that the prevalence of respiratory morbidity appeared to be lower in "blacks". The question of environmental differences accounting for these findings was also dismissed on subjective grounds by several investigators¹⁹⁴⁻²⁰⁴ and it was therefore concluded that genetic differences existed.

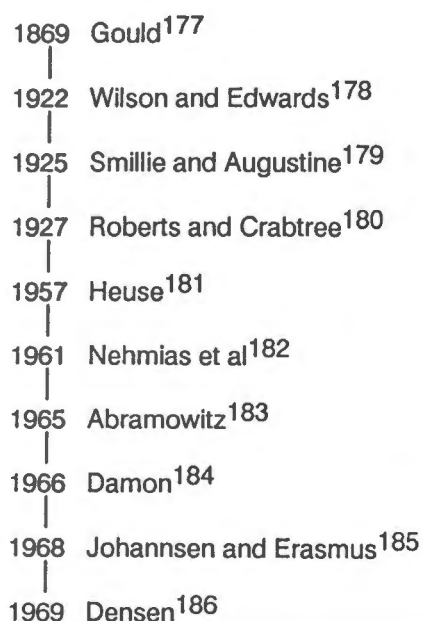


Fig. 3 (i) Date line - Early investigators of "racial" difference in lung function

The methodology used in these studies to select participants, screen for "normality", perform and analyse lung functions varies considerably and does not conform to current accepted minimum standards. For this reason only the study by Johannsen and Erasmus¹⁸⁵ (which is the only early investigation to produce regression equations based on height and age) is examined in the next section.

It is important to realise that as a result of these studies the concept of "racial" differences in lung function originated. This is despite the fact that most of these studies did not set out to examine the precise relationship of "race" to lung function, but came accidentally upon the finding when group comparison analysis techniques were employed. It is not clear as to how such techniques were able to compare groups who did not differ only with respect to the putative determinant; which is a prerequisite for such an analysis. It is possible, therefore, that the concept of "race" differences in lung function has resulted from poorly designed protocols using inappropriate analysis techniques. It is also evident that the concept of race as a biological entity was accepted by the investigators who used superficial indicators such as skin colour to separate groups. It will be seen in Chapter 4 that the use of race in this way may, in fact, be unscientific.

It has been suggested that these differences are genetic (racial) in origin and due to the fact that blacks have smaller height coefficients for lung volumes and generally for flows than whites do. This has been explained by a greater proportion of total height contributed by the lower extremities, although in one study the ratio of sitting height to total height in blacks was no different from other races⁷⁷. Further support for the race differences in lung function has come from studies on Indians^{196,197}, Pakistanis (wherever resident)¹⁹⁸, Orientals^{199,200}, Pacific Islanders²⁰¹ and North American Indians who are generally intermediate between whites and blacks²⁰². Of interest is a recent study by Crapo in which no statistically significant differences in spirometry were documented between American Indians and whites.

This knowledge has not been consistently applied in the clinical interpretation of pulmonary function tests or epidemiologic screening. This section will review the studies (summarised in Tables 3 (i) - 3 (iv)) in which normal values for "blacks" and "whites" have been investigated. The current implementation of these findings will be discussed and the need for further investigations highlighted.

(1) Intra-ethnic differences

It has been suggested that the differences in spirometric volumes exist not only between the major race categories, but within these groups. This question has long been raised concerning the different ethnic groups within the "Caucasian" race in Europe⁴⁹, as well as within the "Negroid" race in Southern Africa⁶. In South Africa the black population is composed of several different sub-groups. It has been proposed that lung volume of these groups are different due to associated differences in anthropometric features⁶. Few objective studies have, however, been done. Recent studies have suggested such differences do not occur.

(2) Current guidelines for ethnic assessments

Clausen⁵⁷, in his extensive review of the problem of deciding which prediction equations to use for a particular race group, makes two major points:

1. Inter-ethnic variations do exist (e.g. between Africans (blacks) and Europeans (whites), and

2. Intra-ethnic variations are unlikely within groups matched for known determining variables (e.g. between Europeans living in Italy or Sweden).

The observed race related variation in lung volumes gave rise to attempts to use well established normal values for white healthy subjects and adapt them by the use of a correction factor to scale down to create reference values for blacks. An alternative suggestion has been to perform local studies of different race groups and to use these as the predictions for each group in each area. Since most studies have shown the difference in FVC and FEV₁ for black adults to be in the range of 10 to 20%, a 13% scaling factor has been proposed to adjust the values predicted for whites¹¹⁷. Dockery, in his study of 1258 white and 1041 black children (6 - 11 years of age), confirmed the 13% difference between the two groups. Further acceptance of this observation was highlighted by the ACCP⁴⁷ recommendation that predicted values of Morris et al⁶⁴ should be reduced by 12% to achieve a reasonable approximation for normal values in blacks⁴⁷. A similar factor, 12.5%, has been used to convert the FEV₁ of East Indians²⁰³. Values for FEV₁/FVC in blacks are generally higher than in whites¹⁹⁵. Important work in the field of correction factors was done by Rossiter and Weil¹³¹ who demonstrated (in a group of 224 male workers exposed to low concentrations of asbestos cement, with no clinical or radiological evidence of chest disease) marked race differences with respect to height and age. They did not take into account socio-economic status or childhood infections, although they did exclude bronchiectasis (possibly resulting from childhood infections). Rossiter pointed out that in a study of miners in Northern Rhodesia²⁰⁴ evidence was produced that for a given height, whites of European descent have 13.2% larger chest volumes (at full inspiration) than blacks of African descent and postulated that this completely accounted for the observed difference in total lung capacity. Rossiter¹¹⁷ derived a scaling factor of 13% and proposed that this should be used to reduce white predicted values for use in blacks. Collateral support for this derived factor, Rossiter argued, came from its similarity with the measured differences found by Damon¹⁸⁴ and Oshervitz¹⁸⁸ in their studies. Myers¹ has challenged Rossiter's conclusions by pointing out that the two categories of miners in Rossiter's study had performed very different work. The black miners were involved in the manual tasks

and had been exposed to much dust and noxious fumes, whereas the whites occupied technical or supervisory posts and worked in a relatively clean environment. Perhaps more important was the marked difference in socio-economic class, the white miners coming from a middle class background, while the black miners came from rural areas with its much higher risk of childhood respiratory infections.

The use of scaling factors is reliant on the acceptance that differences in lung size are proportional¹¹⁷. However, Schoenberg⁶¹, in his important study of the dynamics of pulmonary functions in healthy blacks and whites, and Corey²⁰³ in another sophisticated study, demonstrated that the FVC and different heights and ages could not be related in a "proportional manner". Furthermore, differences of race groups for different lung compartments were not constant and the race differences between lung function in the two sexes were also not constant and may be reversed⁶¹. Schoenberg, therefore recommended the derivation of race specific reference values for pulmonary function in a given society⁶¹. Mengesha¹⁸⁸ has recently suggested that the selection of appropriate prediction equations for blacks should be based on the sitting height/standing height ratio of the population in question. If this ratio is 0.51 (which the investigators suggest is the ratio for whites), then the use of the same set of normal values for different race groups is appropriate. If, however, the ratio for blacks is found to be in the region of 0.49, then separate prediction equations should be used for each race group.

The national agencies responsible for occupational health in the United States (NIOSH and OSHA), in an attempt to standardize practice in pulmonary function programmes in industry, recommended adoption of the values predicted by Knudson et al⁵⁸, with a downward scaling for blacks. This decision was reached after considerable debate, because there was insufficient research data to guide the agencies better and they had to rely on the "current state of the art" in dealing with ethnic differences. In giving evidence on the Final Mandatory Cotton Dust Standard¹⁶⁰, Drs Weil, Harvey, Morgan and Whitworth all agreed with a 15% scaling factor. For FVC Dr Martin proposed an 8% correction factor. Dr Bouhuys dissented and argued that simple scaling factors could not be used to predict racial differences in lung

function. The widespread use of scaling factors to correct the ethnic difference in lung function lacks solid scientific or mathematical validity. The WHO study group¹⁶¹, on the other hand, recommends the alternative approach, namely, that local population studies should be undertaken in order to derive prediction equations relevant to the resident population. The Intermountain Thoracic Society (ITS) recommends the reference values obtained from Crapo's study of Caucasian North Americans of European ancestry⁵². The ITS does not recommend specific prediction values for blacks. They have elected not to attempt to adapt the reference values to other racial groups or, indeed, to other populations. They found that the differences between blacks and Caucasians were too variable to permit the use of scaling factors that would allow adapting predicted values from one group to the other. Their advice to clinical laboratories is to find the reference values best suited to the populations they serve. This should be done for all the racial groups if this is necessary.

The latest ATS³⁰ statement implies acceptance of "race" differences by simply stating that "few" data are available for several race and age groups. It has likewise been suggested that values for TLC be scaled down by 13% white values for FRC and RV reduced by 8%¹¹⁷. It is generally accepted that no differences have been demonstrated in transfer factor between white and black subjects. Rossiter also suggests that transfer factor, being dependent of inspiratory volume (which is racially determined), should be scaled down by 8% for blacks (see page 2, Chapter 3)¹¹⁷. The current ATS³⁰ statement points out that there is little or no information about reference equations for racial groups other than Caucasians.

3.2 REVIEW OF STUDIES GIVING RISE TO SPIROMETRIC REFERENCE VALUES FOR BLACKS

1. Mengesha¹⁸⁸

This study predicts the highest values for FEV₁ among young black males and values for FVC amongst blacks that are similar to those predicted by most studies for whites. Unfortunately, the study was based on a relatively small number of males, 143 in total, of which only 65 were > 28 years of age. The study population was further weakened by the reliance on volunteers, who may have had their own reasons for

TABLE 3 (i): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR BLACK ADULTS HAVE BEEN DERIVED

AUTHOR		LOCATION		POPULATION				NORMALITY SCREEN											
NAME REF	NO.	SITE/ (ALTITUDE)	YEAR PUB	TOTAL N	BLACK MALES	WHITE MALES	POP. BASE U/R	SELECTION W/B	CRITERIA C/B	AGE MEAN (RANGE)	> 25 - < 65 YRS N	DATA NON-ATTENDERS	CXR PA/L FS/M	QUEST. I/V TECH.	NS	OCCUP. HISTORY	SMOKING STATUS	CLIN. EXAM	NORMAL POPULATION (DEFINITION)
Abramowitz 203	01	New Jersey USA (NS)	1964	272	51	60	U/B	H/B	NS	NS	NS	NS	Yes NS	NS	Current only	No	Yes	Yes	No history CVS/Resp disease Normal CXR Co-operate with test No evidence/history of disease able to affect resp status
De Kock 6	02	Namibia (NS)	1988	2500 M+F (1407M)	876	306	U/B	W/B	ALL employees	32.8 <20->65	NS	NS	Yes NS	NS	Yes	Yes	Yes	Yes	Non smokers NS

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based; CXR = Chest radiograph; PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 3 (i) (continued): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR BLACK ADULTS HAVE BEEN DERIVED

AUTHOR		LOCATION		POPULATION				NORMALITY SCREEN					NORMAL POPULATION (DEFINITION)			
NAME REF	NO.	SITE/ (ALTITUDE)	YEAR PUB	TOTAL N	BLACK MALES	WHITE MALES	POP. BASE U/R	SELECTION W/B	AGE MEAN (RANGE)	DATA > 25 - < 65 YRS NON-ATTENDERS N	CXR PA/L FS/M	QUEST. I/V TECH. HISTORY		OCCUP. HISTORY	SMOKING STATUS	CLIN. EXAM
Fox 195a	03	Botswana (860 m)		NS (300)	NS (300)	NS	U/B	W/B Haphazard	NS (20-60)	NS	Yes	NS	Yes	Yes	Yes	Current history URTI Previous COAD + PTB Recent URTI Chest deformity Abnormal CXR Clinical evidence acute and chronic respiratory disease Recent major illness
Huizinga 214	04	Upper Volta (NS)	1968	183 M+F	137	-	R/B	C/B Attempted represent- active sample	NS (7-64)	NS >30<65	NS	NS	NS	NS	Yes	Free of overt signs clinical disease
Johannsen 205	05	Pretoria SA (NS)	1967	220	120	-	U/B	H/B Haphazard	34.7	100	NS	Yes	NS	NS	Yes	NS

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based; CXR = Chest radiograph; PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 3 (i) (continued): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR BLACK ADULTS HAVE BEEN DERIVED

AUTHOR		LOCATION		POPULATION				NORMALITY SCREEN									
NAME REF	NO.	SITE/ (ALTITUDE)	YEAR PUB	TOTAL N	BLACK MALES	WHITE MALES	POP. BASE U/R	SELECTION W/B C/B S/B	CRITERIA	AGE MEAN (RANGE)	DATA > 25 - < 65 YRS NON-ATTENDERS	CXR PA/L FS/M	QUEST. I/V TECH.	OCCUP. HISTORY	SMOKING STATUS	CLIN. EXAM	NORMAL POPULATION (DEFINITION)
Lepp 210	06	West Virginia USA (NS)	1974	9000	79 (23)	316 (69)	NS	W/B ALL	ALL	W35.2 B35.3	NS	Yes Pa/L	MRC NS	Yes	Yes	No	No cough/phlegm No SOB CXR no pneumoconiosis /significant disease FEV1/FVC < 70%
Mengesha 208	07	Ethiopia (1528)	1974	117F 143M	143 (143)	-	NS ?U	C/B	Volunteers	31.79 (18-47)	65 (>28)	NS	NS	BMRC NS	No	Yes	Negative respiratory questionnaire Non-smokers
Miller 211	08	Guyana (NS)	1974	1060 (722)	96 (NS)	129 (NS)	R/B	C/B Random sample	Random	B44.5	B96	NS	Yes NS	MRC NS	Yes	Yes	History of chest illness SOB Blackfat tobacco

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based; CXR = Chest radiograph; PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 3 (i) (continued): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR BLACK ADULTS HAVE BEEN DERIVED

AUTHOR		LOCATION		POPULATION				NORMALITY SCREEN											
NAME REF	NO.	SITE/ (ALTITUDE)	YEAR PUB	TOTAL N	BLACK MALES	WHITE MALES	POP. BASE U/R	SELECTION W/B C/B S/B	CRITERIA	AGE MEAN (RANGE)	DATA > 25 - < 65 YRS NON- ATTENDERS	CXR PA/L FS/M	QUEST. I/V TECH.	MRC NS	OCCUP. HISTORY	SMOKING STATUS	CLIN. EXAM	NORMAL POPULATION (DEFINITION)	
Mustafa 212	09	Sudan (NS)	1977	NS	NS	NS	NS	C/B	Volunteers	B30	NS	NS	NS	MRC	Yes	Yes	Yes	Yes	Never smoked Denied respiratory symptoms Normal Resp/CVS exam No occupational hist. Willing to co-operate
Oscherwitz 209	10	San Francisco USA (NS)	1972	733	110 (98)	554 465	U/B	H/B	Volunteers	W51.7 B50.3	W554 (>38) B108 (>39)	NS	No	BMRC	NS	Yes	Yes	NS	COPD excluded No cough/phlegm most days > 3 months FEV1/FVC < 70%

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based; CXR = Chest radiograph;
 PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 3 (i) (continued): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR BLACK ADULTS HAVE BEEN DERIVED

AUTHOR		LOCATION		POPULATION						NORMALITY SCREEN								
NAME REF	NO.	SITE/ (ALTITUDE)	YEAR PUB	TOTAL N	BLACK MALES	WHITE MALES	POP. BASE U/R	SELECTION W/B C/B S/B	AGE MEAN (RANGE)	> 25 - < 65 YRS N	DATA NON- ATTENDERS	CXR PA/L FS/M	QUEST. I/V TECH.	MRC NS	OCCUP. HISTORY Yes	SMOKING STATUS Yes	CLIN. EXAM No	NORMAL POPULATION (DEFINITION)
Rossiter 68	11	New Orleans USA (NS)	1974	859	462 (147)	397 (97)	NS ?U	NS (ALL)	W40.9 (22-79) B34.4 (21-70)	NS	Yes	Yes NS	MRC NS	Yes	Yes	No	Total asbestos exposure < 1000U No cough/phlegm > 3 months Normal chest X-ray	

NS = not stated; M = Males; F = Females; U = Urban; R = Rural; W/B = Work based; C/B = Community based; S/B = School based; H/B = Hospital based; CXR = Chest radiograph;
 PA = Posteroanterior; L = Lateral; FS = Full size; M = Mobile; (B)MRC = (British) Medical Research Council; Mod = Modified; I/V = interview

TABLE 3 (ii): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR BLACK ADULTS HAVE BEEN DERIVED: TES

AUTHOR		TESTING METHODOLOGY									
NAME	NO.	EQUIPMENT	TECHNOLOGIST	NO. OF TRIALS	SELECTION CRITERIA	FEV1 STARTING POINT	ATS STANDARDS	BTPS CORRECTION			
Abramowitz 203	01	Gaenster- Collins timed vitalometer	NS	NS	NS	NS	NS	Yes			
De Kock 6	02	Cavitron SC20 + Gould Model 80 Spirometer	Technologist	NS	Best loop	NS	No	Yes			
Fox 195a	03	Vitalograph model R Spirometer	Clinic helper	NS	NS	NS	No	Yes			
Huizinga 215	04	Collins Spirometer	Physician	Several	Average of best three	NS	No	Yes			
Johannsen 205	05	Pulmonizer 470 hi-fi spirometer	NS	3-5	Largest	NS	NS	No			

NS = Not stated; FEV1 = Forced expiratory volume in 1 second; ATS = American Thoracic Society; BTPS = Barometric Temperature and Pressure

TABLE 3 (ii) (continued): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR BLACK ADULTS HAVE BEEN DERIVED

AUTHOR		TESTING METHODOLOGY						
NAME	NO.	EQUIPMENT	TECHNOLOGIST	NO. OF TRIALS	SELECTION CRITERIA	FEV1 STARTING POINT	ATS STANDARDS	BTPS CORRECTION
Lapp 210	06	NS	NS	NS	Best of first 3 trials	NS	No	NS
Mengesha 208	07	Vitalograph Spirometer	NS	NS	Best of first 3 trials	NS	No	20°
Miller GJ 211	08	McDermot dry Spirometer	NS	5	Average of best 2 trials	NS	No	NS
Mustafa 212	09	Wedge spirometer	Physician	5	Average of best 2 trials	NS	No	Yes
Oscherwitz 209	10	Electro-med 280 + Collins 9L + Wedge model 270 spirometers	NS	NS	Best of 3 reproducible trials	NS	No	NS

NS = Not stated; FEV1 = Forced expiratory volume in 1 second; ATS = American Thoracic Society; BTPS = Barometric Temperature and Pressure

**TABLE 3 (ii) (continued): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR BLACK ADULTS HAVE BEEN DE
METHODODOLOGY**

AUTHOR		TESTING METHODOLOGY						
NAME	NO.	EQUIPMENT	TECHNOLOGIST	NO. OF TRIALS	SELECTION CRITERIA	FEV1 STARTING POINT	ATS STANDARDS	BTPS CORRECTION
Rossiter 68	11	Water sealed Spirometer (13.5 L)	NS	NS	NS	NS	No	NS

NS = Not stated; FEV1 = Forced expiratory volume in 1 second; ATS = American Thoracic Society; BTPS = Barometric Temperature and Pressure

TABLE 3 (iii) (continued): PREDICATION EQUATIONS (SPIROMETRY) FOR BLACK ADULT MALES

AUTHOR		REGRESSION (PREDICTION) EQUATIONS		STATISTICAL TESTING				PREDICTED NORMAL			
NAME	NO.	FVC (BLACK) FVC (WHITE)	FEV1 (BLACK) FEV1 (WHITE)	R ²	FVC SEE	P	FEV1 SEE	P	FVC (W)	FVC (B)	40 YRS/170 CM (L) FEV1 (B) FEV1 (W)
Miller	08	-2.90 - 0.024A + 4.44H	-1.82 - 0.024A + 3.40H	NS	NS	NS	NS	NS	3.62	3.0	
Mustafa	09	-6.14 - 0.16A + 0.0604H	-3.864 - 0.022A + 0.46H	0.58	0.41	NS	0.52	0.41	NS	2.93	
Oscherwitz	10	-1.48 - 0.027A + 0.094H -1.79 - 0.036A + 0.114H	-0.899 - 0.031A + 0.076H -0.345 - 0.036A + 0.078H	0.16 0.28	0.64 0.65	<0.05 <0.05	0.16 0.31	0.64 0.69	<0.05 <0.05	4.09 4.85	3.24 3.74
Rositer	11	-5.4 - 0.019A + 0.058H	-	NS	NS	NS	-	-	-	3.7	-

A = Age (years); H = Standing height; FVC = Forced vital capacity; FEV1 = Forced expiratory volume in 1 second; R² = correlation coefficient; SEE = Standard error or estimate; L = Litres; W = White; B = Black;

TABLE 3 (iii): PREDICATION EQUATIONS (SPIROMETRY) FOR BLACK ADULT MALES

AUTHOR		REGRESSION (PREDICTION) EQUATIONS		STATISTICAL TESTING				PREDICTED NORMAL				
NAME	NO.	FVC (BLACK) FVC (WHITE)	FEV1 (BLACK) FEV1 (WHITE)	R ²	FVC SEE	P	R ²	FEV1 SEE	P	FVC (B) FVC (W)	FEV1 (B) FEV1 (W)	
Abramowitz	01	-3.82 - 0.018A + 0.051H -7.24 - 0.016A + 0.072H	-								4.13 4.36	- -
De Kock	02	-2.28 - 0.03494A - 2.79 -1.64 - 0.02179A - 5.22	0.03147H - 0.03101A + 0.0612Hcm 0.04037H - 0.01846A + 0.0406Hcm	0.26 0.36	NS NS	NS NS	0.25 0.41	NS NS	NS NS		3.37 3.95	2.83 3.18
Fox	03	-5.24 - 0.0081A + 0.0566Hcm	-3.28 - 0.0199A + 0.0439Hcm	0.32	NS	NS	0.30	NS	NS		4.06	3.38
Huizinga	04	-4.56 - 0.0189A + 0.0518Hcm	-3.99 - 0.0280A + 0.0454Hcm		NS	NS		-	-		3.49	2.61
Johannsen	05	-2.84 + 0.0375Hcm	-1.19 - 0.0156 + 0.023Hcm	0.45	NS	NS	0.44	NS	NS		3.53	2.09
Lapp	06	-1.84 - 0.021A + 0.040Hcm	-1.54 - 0.025A + 0.035Hcm	0.36	0.32	NS	0.45	0.23	NS		4.12	3.41
Mengesha	07	-6.6839 - 0.0195A + 0.0695Hcm	-2.9208 - 0.0122A + 0.0407Hcm	0.39	0.58	<0.05	0.39	0.58	<0.05		4.35	3.52

A = Age (Years); H = Standing height; FVC = Forced vital capacity; FEV1 = Forced expiratory volume in 1 second; R² = correlation coefficient; SEE = Standard error or estimate; L = Litres; W = White; B = Black;

TABLE 3 (iv): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR BLACK ADULTS HAVE BEEN DERIVED: INVESTIGAT

AUTHOR	REGRESSION COEFFICIENTS			RACE vs SOCIO-ECONOMIC STATUS			STATISTICAL METHODOLOGY		
	NAME	HEIGHT	AGE	OTHER	RACE	SOCIO-ECONOMIC INFLUENCE ANALYSED		DISCUSSED	RELATIVE INFLUENCE ANALYSED
Abramowitz	01	St H	A	BSA	Negro Black	No	No	No	Multiple regression
De Kock	02	St H	A	Sit H	Namibian Black (Ovambo) White (NS)	No	Dismissed	No	Stepwise linear regression
Fox	03	St H	A		Botswana (Tswana) Black	No	No	No	Least-squared regression
Huizinga	04	St H	A	Sit H Wt	Upper Volta Black (Kuramba)	No	May contribute	No	Multiple regression
Johannsen	05	St H	A	W	S A Black	No	No	No	Product moments correlation matrix Stepwise linear regression

St H = Standing height; A = Age; W = Weight; BSA = Body surface area; Chest circ = Chest circumference; Cigs = Cigarettes

TABLE 3 (iv): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR BLACK ADULTS HAVE BEEN DERIVED: INVESTIGAT

AUTHOR	REGRESSION COEFFICIENTS			RACE vs SOCIO-ECONOMIC STATUS			STATISTICAL METHODOLOGY		
	NAME	HEIGHT	AGE	OTHER	RACE	SOCIO-ECONOMIC INFLUENCE ANALYSED		DISCUSSED	RELATIVE INFLUENCE ANALYSED
Lapp	06	St H	A	-	Negro Black	No	No	No	Analysis of variance
Mengesha	07	St H	A	W/H ² / % fat & H	Ethiopian Black	No	May contribute	No	NCR multiple regression programme
Miller GJ	08	St H	A	W	Guyan Black/ Indian	No	Yes - all same class	No	Multiple regression Multiple co-variance analysis Students t test
Mustafa	09	St H	A	-	East African Black	No	No	No	Multiple regression
Oscherwitz	10	St H	A	-	Negro Black	No	Dismissed	No	Multiple regression Newman-Keuls test

St H = Standing height; A = Age; W = Weight; BSA = Body surface area; Chest circ = Chest circumference; Cigs = Cigarettes

TABLE 3 (iv): STUDIES FROM WHICH PREDICTION EQUATIONS (SPIROMETRIC) FOR BLACK ADULTS HAVE BEEN DERIVED: INVESTIGAT

AUTHOR	REGRESSION COEFFICIENTS			RACE vs SOCIO-ECONOMIC STATUS			STATISTICAL METHODOLOGY	
	NAME	NO.	HEIGHT AGE OTHER	RACE	SOCIO-ECONOMIC INFLUENCE ANALYSED	DISCUSSED		RELATIVE INFLUENCE ANALYSED
Rossiter	11	St H A	13% scaling factor	Negro Black	No	Dismissed	No	Multiple regression

St H = Standing height; A = Age; W = Weight; BSA = Body surface area; Chest circ = Chest circumference; Cigs = Cigarettes

participating. These factors, together with the paucity of information regarding the profile of non-attenders (the total population), makes it difficult to extrapolate their findings to the general population. The lack of information concerning occupational and environmental exposure detracts from the screening of the population. Although only non-smokers were included, it is not clear as to the precise definition of a smoker, and also as to whether previous smokers are included. Pulmonary function survey testing is particularly difficult in populations where the language spoken is not that of the questionnaire used, or technologist involved. This may have influenced the outcome of the BMRC questionnaire and lung function testing. Very experienced interviewers and technologists would have been required, but it is not clear as to whether this in fact was the case. The analysis of the best blow of the first three attempted is unfortunate, as this does not necessarily meet ATS⁵¹ requirements (that three acceptable traces be obtained before the best of these is accepted for analysis). Analysis of co-variance resulted in a R^2 value of only 0.39. This was despite careful attempts to look at various anthropometric variables and their exponentials. The authors discussed the possibility that socio-economic factors may also have contributed to lung functions, but they did not test for this objectively.

2. Rossiter¹¹⁷

This author's conclusion that a 13% correction factor is an accurate technique for adjusting prediction values for white subjects, so that they may fit blacks, has had a major influence on the current understanding of lung functions in different race groups. This conclusion was reached from a small group of only 147 blacks, 97 whites, and included smokers in the black group. Although all were selected from a work-based study of all workers in asbestos cement factories, it is unlikely that the two race groups occupied the same place in the work force. It is most likely that the blacks worked in jobs with greater exposure to asbestos cement. Although only workers whose total exposure of less than 1000 units (where one unit of exposure to 1 million particles of respirable dust per cubic foot of air for one month), a large discrepancy is likely to have been present within this relatively high "safe range". It is also most likely that the different positions in the work force are indicative of different socio-economic backgrounds, which may also have influenced the pulmonary functions obtained. The mean age of the

two groups, 40.9 years for whites and 34.4 years for blacks, is also significantly different. A large number of blacks must have been under the age of 25 years and the concomitant immaturity of their lungs may have contributed to the smaller volumes obtained. The normality screen was extensive, but the inclusion of smokers as already alluded to, may have adversely influenced the results. Difficulties experienced and the precise method employed in the administration of the questionnaire are not clearly demonstrated. It is possible that workers in the lower work place may have experienced difficulties in understanding the questionnaire, or been more guarded in answering positively to symptoms for fear of losing their jobs. The testing methods are not clear and may not have met current standards⁵¹. The data on which the derivation of the scaling factor was based is therefore difficult to accept in a study with so many possible pitfalls. Even if none of the pitfalls were encountered the suggested use of proportional differences cannot necessarily be extrapolated for use in other studies. The authors, in their discussion, dismissed the role of socio-economic factors without objective rationale for such a dismissal.

3. Oscherwitz¹⁸⁹

This study is often quoted in the literature. The study compares the lung functions of only 98 black men with 465 white men, all of whom were volunteers. The population studies were further compromised by the inclusion of patients in a hospital based study. These factors are likely to have resulted in a group poorly representative of a general population. The normality screen only excluded those patients with a history of chronic bronchitis and/or those whose FEV₁/FVC ratio was lower than 70% on the day of testing. Smokers and non-smokers were also included in the group analysed. Their use of three different types of apparatus makes interpretation of the results difficult, despite the validation exercise outlined by the authors. The study does not meet current standards, although the best of three reproducible blows was used in the analysis. In addition to these pitfalls, it is most unlikely that the two racial groups enjoyed the same socio-economic and environmental backgrounds. This factor was dismissed in the discussion without objective evidence.

4. Lapp¹⁹⁰

The prediction equations produced in this study are recommended by the ITS. The pulmonary functions were performed as part of a massive inter-agency study of coal worker's pneumoconiosis. From a total population of 9000 men, only 79 black males and 316 white males were finally analysed. Of this group, only 23 black males and 69 white males were healthy never smokers. The testing methods did not meet currently accepted standards⁵⁸. The best blow of only three attempts (following two practice blows) were used in the analysis. The analysis was performed for the three smoking groups, viz previous, current and never smokers. The small numbers in the three groups make the results difficult to interpret. Finally, the influence of socio-economic factors was not addressed.

5. Miller¹⁹¹

This community based study of rural Guyanans was executed following a careful selection of subjects. Following a private census of households in the area all were asked to participate. Seven hundred and twenty-two of 1060 participated in the study, including 96 blacks. Despite an extensive normality screen, all smoking categories were analysed together. The adverse effect of this approach is complicated by the paucity of information regarding the different profile of smoking habits. The interpretation of the results is further confounded by the use of the average of the best two of five trial blows. This does not meet current ATS recommendations⁵⁸. The comparison of the two racial groups was thought to be justified as it was felt that the two groups were standardised for socio-economic factors. Without objective evidence, it is difficult to accept this statement.

6. Mustafa¹⁹²

This study compared the pulmonary functions of three groups, black East Africans, South Sudanese and North Sudanese. The study population was reliant on volunteers and this detracts from the interpretation of the results. Although radiographs were not performed, the normality screen was extensive and only the most healthy never smokers were included in the analysis. This clear definition of normality enhances the study, but in combination with the use of volunteers, the population study may well have

been supernormal. Testing methodology did not meet ATS standards, and the use of the average of the best two blows makes interpretation of the results difficult. Socio-economic factors are not investigated and this further weakens the findings and makes comparison with other studies difficult.

7. Seltzer¹⁹³

The main purpose of this study was to investigate the inter-relationships of smoking habits and race on pulmonary function. No reference equations for normal values were produced. The study is included in this review, however, because of the large number of never smoking "White" (7481) and black (992) males studied. "White" never-smokers and had significantly higher mean values for FVC, FEV₁ and PEF than the respective age and height specific "blacks". Although each individual participated in an extensive medical check-up it is not clear to what length minor, but significant, cardiorespiratory disease was screened for, nor is it clear as to whether the black and white "race" groups differed in respect to their "health" screen results. This may be one of the reasons differences were demonstrated for spirometric measurements between the race groups. The use of 2 pieces of equipment, despite attempts by investigators to minimise the problems associated with this practise, detracts from the quality of data performed. The quality of the data is further compromised by the lack of internal standardization of selection of the best trials, as well as the fact that the methodology used does not meet currently accepted standards. Finally, social stratification influences are not objectively investigated and no mention of childhood backgrounds with regard to either social stratification or passive smoking is examined. These factors may all have contributed to the findings in this study.

8. Johannsen and Erasmus¹⁸⁵

This investigation was one of the first investigations into the lung function of blacks in South Africa. The results of this study are still used in certain pulmonary function laboratories in South Africa. The methodology employed and equipment used falls short of currently accepted minimum requirements. All participants were haphazardly selected by their "superiors", so making it difficult to infer anything concerning the representativeness of the study population to the general population. This difficulty is

further compounded by the lack of definition regarding the definition of "normality". The authors compared their results with the results of other population studies and found that their subjects had significantly smaller lung volumes even when corrected to BTPS, which was not done by the investigators. No attempt was made to objectively examine the influence of social stratification. It is, however, most probable that "blacks" in South Africa, at the time of the study (published 1966), occupied a much lower social stratification position than the other population against whom they were compared.

9. Huizinga and Glanville¹⁹⁴

Spirometric measurements were included as part of an extensive investigation into the human biological characteristics of African populations. The problems encountered in studying populations who differ from the investigators with respect to language and customs is well demonstrated by the difficulty to estimate the demographic profile of the study population and the establishment of accurate ages. Age is an important determinant of lung function and thus doubt in the accuracy of ages makes interpretation of spirometric values difficult. It is likely that this problem is encountered by most investigators in this field, but is rarely commented on. The small sample size of 50 adult men between the ages of 30 and 65 years of age (by which stage lung maturation should be complete) weakens this study. The testing methodology and analysis of the average of three best trials also does not conform to ATS standards and therefore makes comparison of these results with other studies difficult. Although the investigators do not objectively examine the relationship between social stratification influences and lung function, they do emphasize the fact that their study population live in a very harsh rural environment and that these factors should be considered in relation to this fact. Importantly, these investigators conclude that the evidence supporting a genetic basis to "race" differences in lung functions "reflects well our ignorance of the basic factors underlying population differences".

10. De Kock⁶

The prediction equations in this study were derived from the data obtained during the first part of a prospective study of the lung function and dust exposure of workers at Southern African a uranium mine.

Although the authors cautioned that the prediction equations produced were not meant for general use, the study is reviewed here because of the conclusions drawn by the investigators regarding "race" differences in lung function. The entire work force (2500 individuals) is subjected to pre-employment examinations, as well as to subsequent examinations, depending on the individual's occupation and smoking habits. In the current investigation the results obtained from 1407 male workers is presented. It is unfortunate, however, that it is not clear as to whether the "non-smokers" were in fact lifelong never-smokers or included individuals who had smoked up to two years previous to the commencement of data collection. It is also not clear as to whether the individuals studied were similar with respect to the prevalence of cardiorespiratory symptoms. Although the investigators point out that extensive measures are taken to protect workers from possible exposure to dust containing silica and radioactive materials the potential problems in drawing conclusions about normal lung functions from individuals working in a "dirty" environment cannot be ignored. It is also clear that the distribution of occupations is different for the three race groups (viz. blacks, mixed race and whites). It is likely, when one examines the occupations performed, that "blacks" (51.79%) work in potentially more "dirty" environments than the "whites" (29.44%). There is no information about childhood respiratory illness, nutritional status, social stratification status, past occupational or environmental exposures or current income level. Interpretation of observed spirometric differences between race groups should take these differences in exposure to potentially adverse respiratory influences into account. The methodology of lung function testing does not apparently conform to internationally accepted standards. It is also not clear as to how many individuals achieved two "identical" loops and therefore it is difficult to be certain of the quality of the data obtained. In the discussion the investigators point out that although socio-economic factors may influence lung function, they do not feel that there is a place for a universal reference standard. It is not, however, clear as to how such a dogmatic conclusion can be reached given the wide range of confounding variables discussed above. In addition, race is defined by rigid criteria which are not necessarily scientific (see Chapter 4). The gradation in lung functions between the three race groups could as easily be ascribed to the fact that mixed blood individuals occupy social stratification positions between those of whites and blacks.

11. Fox^{195a}

This study was published recently as an attempt to offer a guide as to the normal values for blacks in Southern Africa. As with De Kock's study, they were based on data collected from mine workers. The investigators point out that these workers were exposed to a dusty work environment including sulphur dioxide. No attempt was made to exclude individuals with respiratory symptoms and smokers were included in the analysis. All these factors detract from the use of these values as "normal standards" for other populations. The use of these standards as "in house" standards is also questionable due to the difficulties in separating out the various influences on lung function over time. The quality of the lung function data is also not clearly stated as no mention is made of the technique used to ensure acceptability and reproducibility of traces. The validity of using the best FEV₁ and best FVC from different traces is acceptable. The regression analysis is also based on large numbers of individuals under 30 years of age, whose lung maturation is unlikely to have been completed. Another potential difficulty with this study is the uncertainty as to the exact nature of work the subjects perform and thus the possibility that influences such as the healthy worker effect might exert. This may explain why the predicted values for blacks in this study are greater than those found for blacks elsewhere.

3.3 COMPARISON OF RACE STUDIES**(1) Overlap between white and black predicted normals**

A comparison of the above studies with each other and with the most commonly used prediction equations derived from whites is presented in Tables 2 (iii) and 3 (iii). The highest values for FEV₁ values among young black males are predicted for Ethiopians by Mengesha and Menkonnen¹⁸⁸. The values are in the same range as predicted by many studies for whites. Next highest among blacks is the study by Lapp et al¹⁹⁰ and Fox^{195a}. The studies by Miller et al¹⁹¹, Schoenberg et al⁶¹ (this study is reviewed in Chapter 2), Rossiter and Weil¹¹⁷, Cooksen et al²⁰⁶, Johannesen and Erasmus¹⁸⁵ and Oscherwitz et al¹⁸⁹ predict a range of lower values. The lowest values came from the study by Huizinga and Glanville¹⁹⁴.

The study by Mengesha and Menkonnen¹⁸⁸ also predicts a more rapid decline of FEV₁ with age than most other studies. Lapp et al¹⁹⁰, Johannesen and Erasmus¹⁸⁵ and Schoenberg et al⁶¹ predict less rapid rates of decline among blacks. Schoenberg et al⁶¹ also predict a less rapid rate of decline of FEV₁ than most other studies of Europeans in the eight ranges considered. The studies of Europeans by Morris et al⁶⁴, Knudson et al⁵⁸, Kory et al²¹, Cotes¹⁶⁵ and Higgins and Keller⁶⁷ can be grouped together as predicting similar values for FEV₁ and a similar rate of decline of age. The lowest values for FEV₁ in White males are predicted by Ferris et al¹⁰⁷ and these are lower than values predicted for Africans in the current study, Lapp et al¹⁹⁰ and Mengesha and Menkonnen¹⁸⁸.

The comparison of predicted FVC values among males are similar to the comparison of FEV₁. The Ethiopian study¹⁸⁸ predicts values for FVC amongst Blacks that are similar to those predicted by most studies for Whites. White's²⁰⁵ study and that by Lapp et al¹⁹⁰ and Fox^{195a}, predict almost identical values for FVC and these are also higher than some of those predicted for Whites. In their study of Africans and Europeans Schoenberg et al⁶¹ predict the least rapid rates of decline with age in the age range studied. In the case of FVC, Mengesha and Menkonnen's¹⁸⁸ study does not predict a more rapid rate of decline of pulmonary function, but it is similar to most other studies. The study by Myers¹ of a population of South African stevedores exposed to asbestos, predicts a more rapid rate of decline of FVC with age than do most other studies. These findings do not support previous assertions that there are simple proportional European African differences in pulmonary function. The various studies of African populations have also yielded strikingly different results.

(2) Specific Pitfalls With These Race Studies

From the above comparisons of the expected values for FEV₁ and FVC among men of European and African descent it is apparent that there is a range of values for both groups and that the values for the African populations are generally lower. There is an area of overlap between these two ranges in the similar values predicted by Ferris et al¹⁰⁷, Higgins and Keller⁶⁷, Lapp et al¹⁹⁰, Mengesha and Menkonnen¹⁸⁸ and White²⁰⁴. This observation raises doubt regarding the previously quoted assertion

that there are simple proportional European-African differences in pulmonary function. Various studies of African populations have also yielded strikingly different results. Examples are the differences between Ethiopians¹⁸⁸ and inhabitants of the upper Volta¹⁹² and the difference between two South African studies, Johannesen and Erasmus¹⁸⁵ and White²⁰⁵. Thus, the question arises whether the observed differences in spirometric values between whites and blacks (and also observed among different groups of blacks) arise from methodologic flaws in the surveys, from real genetic factors or from factors associated with being black (generally a poorer socio-economic and environmental background).

Methodologic flaws may stem from the range of values for pulmonary function observed within any broadly defined population group described as "Europeans" (whites) or "Africans" (blacks) and the difficulty in obtaining a representative sample. Examples of this among populations of European descent is the difference between the studies of Ferris et al¹⁰⁷ and Morris et al⁶⁴. Similarly, there is a range of predicted values for populations of African descent, the upper limits of which are demonstrated by White's study²⁰⁵. This explanation would be consistent with the view expressed by Clausen⁶⁴ that there are no intra-ethnic variations within groups matched for known determining variables. It does not, however, lend any weight to the hypothesis that there are intra-ethnic differences in pulmonary function which are in any sense "proportional".

An alternative explanation is that the differences which have been ascribed to race are due to other population differences, many of which have not been evaluated or are not easily quantitated in epidemiological studies of pulmonary function. White²⁰⁵ exemplifies this fact by pointing out that the subjects of his study are likely to have experienced a higher prevalence of malnutrition, of poorly treated respiratory disease and of an environmental pollution in early childhood than their more privileged counterparts in North America, who comprised the subjects of studies such as those of Knudson et al⁵⁸ and Morris et al⁶⁴. As the most rapid rate of increase in the alveolar numbers and size takes place in the first five years of life²⁰⁷, growth retardation through malnutrition in childhood could be responsible for lower lung function in adult life. Socio-economic differences are also important in the light of evidence

that environment in the early years of life can produce adverse changes which persist through life and contribute to the development of chronic respiratory disease²⁰⁸. On the other hand, the high values in White's study as compared with other studies of blacks could be attributed to the exclusion of smokers or the selection of that segment of an underprivileged population who have not only survived the hazards of fatal childhood illness (15% of deaths in blacks each year in South Africa are under the age of 5 years), but who are also healthy enough to become, and remain, industrial labourers. White also points out that another contributing factor could have been the care taken to ensure that subjects understood what was required of them in the first encounter of the spirometer, and the fact that "best values" were used. The fact that 16 years separate the two South African studies may suggest that an improved health status relating to better nutrition and housing of urban workers in South Africa during this time period may explain the considerable differences.

3.4 CONCLUSION

Following on the study by Myers¹, White's study²⁰⁵ is the second South African study of pulmonary function of black workers that have shown higher values than would be expected from previous studies. These findings raise the possibility that inappropriate reference values may be in use and emphasise the need for investigation of reference values amongst South Africans². If one accepts that the presently used reference values for blacks based on proportional differences derived from spirometric surveys of whites are not acceptable, two options are open. The first, following the practice of Schoenberg et al⁶¹, is to determine racially specific reference values for pulmonary function in our society. Such studies would need to evaluate the effect of economic and social influences which could contribute to differences in pulmonary function when populations of Africans and European descent are studied. To date, no such study has been performed where environmental factors have been controlled. The second option is to reject the concept of race specific predicted values for pulmonary function and to accept that in pulmonary function, as in human growth, there is a universal human potential that is profoundly influenced by the environment. This means that we should be determining reference values for pulmonary function that are applicable to the whole population.

CHAPTER 4

4. RACE AND SOCIAL STRATIFICATION: CONCEPTS AND CONTROVERSIES

4.1 RACE

4.1.1 Introduction

Review of the studies on lung functions in different population groups demonstrates a definite paucity of information regarding the precise definition of populations studied. In particular, studies of lung functions in relation to race and social stratification tend to lack adequate information regarding their analysis of these factors. It is also apparent that the controversy regarding race and lung function may in fact be the consequence of misconceptions concerning race. This chapter examines the concepts of race and social stratification and the methodological difficulties in their investigation.

It has been suggested that the concept of race has no biological basis and that any research in which racial groups are separated and compared are irrelevant and unscientific²⁰⁹.

Medical research has always analysed the relationship between groups (variably defined) and health parameters. Most medical studies divide study populations into groups, linked together by some common bond. A frequently employed analysis is the division into what is glibly called "race groups" for analysis of racial differences. The usual divider is the phenotypic characteristic of skin colour. In utilizing this approach the medical profession defines race by skin colour and implies that different skin colour is indicative of a unique set of genes, giving rise to a homogeneous group of individuals who differ significantly from a group with a different skin colour. Implicit also in this approach is the belief that race exists as an easily defined entity. This approach can at best be viewed as simplistic but, more likely, as grossly incorrect and misleading, with profound effects on society.

Cooper²⁰⁹, in his review of the subject, points out that differences in virtually all observations have at some stage been attributed to genetic differences between the groups. Rheumatic fever (a common infectious disease) was observed in the early 1800's to be most common in Irish immigrants. It was postulated that this was due to a racial susceptibility linked to genes for red hair. The disease, however, disappeared from the Irish group as they became more prosperous, to recur in black migrants from the rural south. Classic studies on rheumatic fever have, however, demonstrated the risk to be associated with poor socio-economic status²¹⁰. Anthropometric differences have also been attributed to different race groups. Analysis of paediatric growth charts have suggested that differences exist between different race groups. Recent investigations have demonstrated that these variations are due to socio-economic differences²¹¹.

A clear understanding of the concept of "race" and its relationship to development and function of the lung is pertinent to this study.. The relationship between race and health was recently reviewed by investigators from all the cognate disciplines²¹². This chapter will address the question of race while the relationship between race and social class will be dealt with in the discussion.

4.1.2 Concepts of Race

The concept of race might at first sight be thought to be simple and obvious. The precise meaning of race has been contentious since it was first introduced some 200 years ago²¹³⁻²²⁰. Montague, in his excellent review of the subject, points out that the concept of race, as applied to man was first put forward by Buffon in 1749 as an arbitrary classification, serving only as convenient label and not a definable scientific entity²¹³.

During the 19th century the concept of race was popularised as the evidence for evolution began to accumulate. Scientists initially anticipated that it would be the key to human history, the key that would explain why persons of the world differed so much in their civilisations and in their technological achievements. Three major race theories evolved: (1) Biological (Zoological); (2) Anthropological and

(3) Sociological. These will be discussed in the following paragraphs.

(a) Biological Notion of Race

Zoologists have settled on the taxonomic classification of plants and animals. The animal kingdom may be divided by biologists into more than a million basic species. Members of the same species can mate and produce fertile offspring. Members of the same species look alike and act alike, but within a species one is able to recognize the existence of clear sub-divisions (e.g. dogs). A sub-group is therefore defined as a breeding population characterized by frequencies of a collection of inherent traits (genes) that differ from those of other populations of the same species. It is not the uniformity with which an inherent characteristic appears, but the comparative frequencies that defines a race. Races are breeding populations not only in a current or instantaneous sense, but also in a historical sense. Members of races represent samples from pools of inheritance, generations in depth.

This taxonomic classification of plants and animals allows an understanding of the evolutionary process and produces a framework for examining the present variation in the zoological kingdom. A taxonomic classification is a rigid structure into which the products of the complex process of evolution is conveniently classified. Proponents of such a classification point out that no classification is absolute. Watts cautions the blind acceptance of a taxonomic classification by pointing out that "... forcing the results of a dynamic and multiplex process of evolution into a simple two-dimensional set of pigeon holes cannot be done without losing information."²¹⁸. Biologists have attempted to extend the taxonomic classification of mammals by using race as the classification below the species group *Homo sapiens*. However, defining the races of man has never been successfully achieved^{213,,219,220}.

There is no question that human variation occurs. Surface features such as skin colour, eye cast and hair form are familiar and the possibility of sorting groups of people that differ in some way is difficult. The scientific use of the concept of race is often to account for some aspect of human variation²¹². Thus, "race" is held to identify consistent genetic differences between different groups, not simply

superficial markers of variation within the human species. Classical proponents of the biological basis for race believe this to be the case. Curt Stern states this simply "race is a biological phenomenon". This view is shared by other researchers in this field, although it is conceded that "pure races" do not exist and the diversity of constitutions of different races overlap greatly²¹². The American Black, for example, is regarded as a relatively new and hybrid race maintained as a breeding population by social factors (including segregation and custom)²²¹.

The difficulties inherent in attempting to identify groups with consistently different genetic constitutions, the basis of typological thinking, has been highlighted by many investigators²²². These scientists argue that, properly defined, races do exist, but that the typological approach should be abandoned. They point out that every individual has genetically different characteristics. Race differences are compounds of individual differences; they are more often relative than absolute. Races differ in the frequencies of some genes (and their phenotypic expressions), more often than that a certain gene is wholly absent in one race and present in every individual of another. Central to this notion is the regarding of race as a populational phenomenon; a statistical phenomenon and not a typological phenomenon. The tremendous overlap that exists between population groups suggests that to compare them in terms of mean values is not only misleading, but actually pernicious. Adherents of this concept of race point out that the degree of overlap between race groups is progressively increasing. Gene flow is probably the principal factor now reducing the differences between the gene pools of the various human races. Gene flow is best exemplified by study populations in Europe and America. As one moves eastward across Asia, populations merge into one another. The gene pool of North American Negroes (socially defined) is now approximately 30% derived from white ancestry^{223,224}. In South America the amalgamation is considerably greater. Recent work has suggested that the variation between populations is the result of genetic drift rather than adoption. This concept tends to eliminate the importance of race differences from an evolutionary point of view²²².

The study of the phenomenon of race and man is therefore complicated. Early anthropologists believed that the human species was composed of 5 races who each evolved from separate origins with independent evolutionary histories²²⁰. This concept of "pure" races has been largely discredited by modern anthropologists^{213,215}. Two opposing approaches have resulted, either the acceptance of several large races (4 or 5) or the reduction of each population into separate groups for the purposes of naming and not classifying^{212,214}. Further, human variation is primarily discordant and not concordant²¹². As a result, although two groups may be of similar skin colour they differ in other important features such as height, blood type, facial features.

Skin colour is the most commonly used basis for classifying races. This arbitrarily assigns primary importance to that characteristic despite the lack of evidence to support this elevation of importance. The pygmies of Africa, the inhabitants of Southern India, the Australian Aborigines and the natives of the Amazon delta are all dark skinned, but differ in many other ways. Their dark skin colour reflects a common history of environmental exposure to ultraviolet radiation, not a common racial (breeding pool) origin. Thus, a single trait such as skin colour is not an adequate basis for characterising human diversity. No discrete "package" of gene differences has ever been described between two races, only relative frequencies of one or another trait²¹². This phenomenon of a continuous distribution is common to most other biological and medical characteristics. In many cases (e.g. body mass index), it is accepted practice to divide a continuous distribution into discrete categories based on objective (external) criteria (e.g. association with morbidity). This approach has been generalized to the question of racial categories, but for racial traits no such external reference system exists, so invalidating such categorisation.

For the layman and the anthropologist the idea of race includes the notion of stability. Obviously the idea of race has as its basic unit a group of individuals such that its collective genetic inheritance (the sum of the inheritance of its members) tends to remain stable throughout the generations. This occurs if the population is geographically isolated and the influence of an evolutionary force is slight. Thus

defined, there are no two populations with identical hereditary endowment, even among white Europeans in different locations. They will differ in the frequency of certain genes. It is worth noting that although there is a lack of hard and fast dichotomies in race differences (as discussed previously), this does not wholly sustain the view of those theorists that believe that races do not exist at all. For the latter, theorists find it difficult to explain why inhabitants of different countries are recognisably different.

(b) Anthropologists' Notion of Race

There are certain anthropologists who not only dismiss the typological approach, but also view the controversy of race as being meaningless in modern science²²². "Races", they argue, are no more than informational constructs which will linguistically and conceptionally persist only as long as they serve the purpose of their users. Currently, the concept of race has two functions: first, as a pedagogic device for teaching human variation and, second, as a research tool investigating biological variation. This concept, they argue, is not (outside of history) an essential tool for teaching, since variability in individual traits can be taught without reference to grouping approach. Notwithstanding the school of anthropologists who reject race classifications, most modern anthropologists^{212,214} stress that the concept of race is a useful tool of classification. In fact, a large number of anthropologists today define "race" (as do biologists) as a population differing from others by the frequency of certain genes; each population then constitutes a race and this term is no longer classificatory.

The contemporary anthropologist^{212,222} does not regard humanity as naturally divided by skin colour, but as composed of a vast number of populations, each with its own history of development. Taken together they form a continuum such that any attempt at classification according to selected combinations of characters leads to the conclusion that many populations are unclassifiable. The differences between populations are minor in comparison with what is possessed in common. Not only do the majority of hereditary characters vary from one population to another, but each of them shows a wide field of variation within one population (polymorphism). As regards measurable characteristics, the members of a population gravitate around an average value; in almost every case, the distributions of the

individual values of the two populations overlap. For example, if the average height of one population is 10 cm less than that of another, there will be a proportion of individuals in the first population who are taller than some members of the second.

Despite the scepticism (as outlined above) with which many anthropologists view the simplistic concept of "race" it is still routinely used by many biologists and anthropologists^{212,222,225}. The view is supported by arguing that races, species, genera and other categories are facts of nature and are useful for the purpose of communication. In adopting this approach the modern anthropologist is using race in the same context as it was initially introduced as a label of pure convenience. Thus, the enlightened anthropologists use race as a "naming process" in order to compare different groups (with relation to gene frequency, culture, etc) and not as a basis for the classification of *Homo sapiens* on the assumption that races have a structural evolutionary relationship to each other (because of evolution) and that each category has a systematic difference in a package of genes. This view contrasts with the classical biologist's view that different races have a consistent difference in traits.

(c) Sociological Notion of Race

"Race" may also be considered as a sociological concept. Sociologists have demonstrated that in virtually every society composed of groups of people of different skin colours, consistent patterns of differential mortality occur. Most of the international variations in health indices likewise follow racial lines. Although marked improvement has been observed for all racial groups over this century, the fundamental relative differences persist²¹². It is a matter of great contention as to whether these differences can be explained in genetics or environmental influences. It is generally accepted that current evidence favours the latter. Racial inequality is a basic feature of social stratification in the modern world; it reflects the underlying class structure and all its resultant effects. Certain authorities extend this interrelationship to the furthest point, "race does not mark in any important way for genetic traits, rather it demonstrates beyond question the paramount role of social causes"²⁰⁹. This sociological

view that race is a social concept with no specific biological meaning is most attractive, although it may overstate the situation.

Although much of the work refuting the influence of race on health has been related to incidences of disease and mortality, its influence in morphological differences has been refuted in many areas, including childhood height²¹¹. This will be discussed in Chapter 5.

The quest for consistent lung function data for specific racial groups, be it white, black or other colour may therefore be a futile exercise. Given the multitude of factors influencing an individual's constitution and the progressive genetic and environmental variation over geographic areas, it is not surprising that no two studies produce the same results.

The published normative lung function measurements for different "races" based on studies which failed to accurately quantify socio environmental factors were described in Chapter 3. The interrelationships between race, class and environment are complex, but need to be closely scrutinized before differences in lung function in groups of different skin colour are attributed to genetic factors.

It is not possible to escape the observation that race and social class correlate to a large extent; black people tend to be over-represented in the lower socio-economic stratification. Whether this overlap is coincidental, inextricably bound or fallacious is central to the present study. By "fallacious" I refer to those who believe that race groups (in the context of biological entities) do not exist at all and that "race" can be understood only in terms of an indicator of social class²⁰⁹.

In South Africa the link between social class and race has been institutionalized. In virtually all other societies the same situation exists in practice, despite the removal of race classification from the legal statutes. In liberal westernized communities it is believed that the racial differences in social stratification has diminished, but it certainly existed 30-40 years ago when the adults studied in medical surveys

published during the last decade were children. Recent work to measure this inequality of social class by determining the ratio of black to white median income, confirms that it is this economic (sociologic) reality that has resulted in the concept of race surviving despite the lack of biological support for it²²⁶.

4.1.3 Conclusion

The study of differences in lung function measurements in different race groups is complex and perhaps even futile. The notion that skin colour is an indicator of pooled genetic characteristics which code for significant biological variation (the definition of race) is currently rejected by many authorities. There are investigators who believe that clearly definable races do not exist, whereas others believe that it is almost an entrenched law of nature. If race is indeed no more than a sociological concept then studies into race group differences are meaningless. If, on the other hand, racial groups are to be identified, then a more precise framework which gives broad categories of gene distribution will be required in order that their identity might be based on scientific grounds. It is also important that the evolutionary history of the different race groups under study should be considered. Finally, the relationship between the "race groups" and social stratification need to be explored before differences may be attributed to race itself. The methodology that may be employed for such an investigation will be outlined in the subsequent chapters.

4.2 SOCIAL CLASS

4.2.1 Introduction

The relationship between social stratification, race and lung function has already been alluded to. The concept of an entity such as social stratification, like that of race, is extremely controversial and emotive. In this section the current concepts of social stratification will be discussed.

In its simplest sense social stratification refers to a "gradation" within a society of the population to have at their disposal those attributes consistent with the best chance of survival. What these "attributes" are and what constitutes "survival" differs between "politico-economic" systems and within cultural and

religious groups. Social stratification deals with the unequal distribution of goods, power and prestige. It is a system of social inequality which ranks families into groups or strata, according to their share of socially valued rewards²²⁷. "Health" in its broadest sense is linked to the availability of these "attributes" to a population. This will be examined in the next chapter in greater detail. It is neither clear what exactly these "attributes" are, nor is it known how to quantitate selected "attributes" in order to examine their relationship to groups within the population.

4.2.2 Concepts of Social Stratification

The concept of social class is a topic of active research and debate amongst sociologists and related disciplines. Two central concerns of sociologists are the tenets of inequality and social stratification, which themselves have common areas of overlap and interrelationship. Social stratification is an important sociological concept for two reasons. Firstly, in all known societies some measure of inequality in the distribution of valued resources exists. The most obvious include variations in wealth, power and prestige. It is important to understand that these extremes of wealth and poverty exist both in wealthy industrialized nations (e.g. USA), "poor countries" (e.g. Bolivia), as well as within classless societies (e.g. Russia)^{228,229}. Secondly, social stratification offers a perspective of society. Although all individuals are similar in terms of biological characteristics, societies are organised on the basis of elaborate systems of differences and distinction, by which the "type of person" is classified and accordingly, how the person is perceived (e.g. skin colour, religion, IQ).

The process by which societies are organised is the process of social differentiation. In theory this organisation could be based on any criterion, no matter how trivial. In practice, members of particular cultures prefer certain distinctions rather than others; age, sex, economic standing, religion being the most common. The way in which societies organise themselves may be informal (e.g. the identification of an elderly group) or formal (e.g. the armed forces).

Several systems of social stratification exist²²⁹. These range from rigid systems including slavery, feudalism and caste, to more open systems such as social class and estate. The caste system is similar to the feudal system, in that most emphasis is placed on the position into which an individual is born. The system is traditionally associated with India and the Hindu religion. In recent years it has been suggested that the concept of caste can be applied to other societies which stresses inborn characteristics as the most important criteria for stratification. Thus, South Africa, which distributes social prestige and economic rewards on the basis of colour, may be described as a caste society²⁵⁰. It has, however, been demonstrated that even in free societies such as Britain, this distinction also applies^{230,231}. Most western capitalist societies have adopted social class, based on economic differences, as the key term for accepted social stratification^{229,231,232}.

Social stratification is not static. Firstly, vertical stratification or pilarisation occurs in addition to the horizontal divisions of social class; as exemplified by race. A black person may hold a senior position in society, but may be demonstrated to share the same "attributes" as other blacks performing the most menial tasks. Blacks in both Britain and the USA (as well as elsewhere) suffer discrimination in education, housing, employment and social status generally, even though legislation specifically forbids such overt discrimination^{229,230,231}. In South Africa skin colour is the crucial determinant of status and economic and academic opportunity and is actually enshrined in the law. Secondly, social classes are not fixed or self-contained, nor easily defined and there is a great deal of social mobility both between and within conventional class categories. Therefore, any attempt to specify boundaries of a class presents a complicated problem.

4.2.3 Causes of Social Stratification

The observation of social stratification as an important feature of every society has been explained in various ways^{229,233,234}. In terms of functionalist (as opposed to egalitarian theory), regular recurring patterns of social activity are maintained because they make some contribution to, or fulfill some function in, the overall working of society. In terms of functionalist theory, inequality is both inevitable and

necessary within a society to promote motivation towards attaining more important and rewarding roles. This results in the less talented individuals falling to the bottom. Functionalists therefore support the correlation between education level and income, and occupation achieved. Another fundamental premise of the functionalist is that society is based on shared values and beliefs. Functionalists regard society as being composed of a series of bands based on status. Inherent in this theory is that over a period of time social inequality will narrow and everything will approximate to the mean. Functionalist adherents have attempted to account for the disadvantaged condition of blacks throughout the world on the basis of consistent failure in education. This, they argue, is due to the presumed inequalities of their culture.

Similar to the functionalist theorists, another group of sociologists, the adherents of Max Weber²³⁴, emphasize the importance of status. Weber argues that a person's position in a social stratification structure is determined by the ability to obtain a supply of goods, external living conditions and personal life experiences. This ability is itself determined by the interrelationship of class and status and, a third factor, power. Weber, unlike Marx²³⁴, gives great emphasis to the importance of status in social stratification. The social model of Weber²³⁴ sees society divided into the economically-based groups called class, cut across by a series of status divisions.

Recently a new school of sociological thought has developed, broadly under the banner of "conflict and power"²²⁸. They argue that a society needs all walks of professions and that the importance of any job is not determined by the reward obtained, but by the importance of the job. In contrast to functionalists these sociologists propose a "conflict and power theory". This theory suggests that the prize jobs and wealth of society are not fairly distributed on a talent basis. Certain people inherit wealth and opportunities and so obtain good jobs, not as a result of talent, but because their parents are able to give them special advantages (e.g. good home life, health care and education). Some people therefore have an advantage in their pursuit of top jobs. Within the "conflict power" theorists there are two major views. Firstly, Marxists, who argue that class structure in capitalist societies is based on power and not the

needs of society^{228,234}. This power is in turn based on the technological (means of production) and economic system of the society. Marxists emphasize only two social strata, those of the bourgeoisie (owners of property and means of production) and the proletariat (workers). Marxist analysis rejects any notion that it is necessary to have inequality. Secondly, sociologists such as Dahrendorf²³⁵ argue that social class is the result of the majority of resources being distributed according to the need of those with power, whereas only a small percentage are distributed according to the needs of the powerless majority. Lenski²³⁶ holds that the bare minimum of resources were distributed within a society, just sufficient to keep it functioning so that the elite upper class could control the result. This argument is closely related to the debate surrounding the relationship between race and class discussed in the previous section.

4.2.4 Social Stratification in South Africa

It can be accepted that social stratification does exist within every society. Inequality in the distribution of positions (be they material, educational or other) clearly do exist. In South Africa social stratification spans a very wide range. So wide in fact is this gap that two societies have been identified, being the developed "first world" and developing "third world". It is broadly accurate to describe the "third world" sector as being comprised of black people, and the "first world" of white and mixed race. Although some overlap does occur, this is both insignificant in terms of numbers and so recent an event that it probably has not had time to make any impact on the society. Although very large amounts of money has been spent to promote general housing, education and health services of the Third World sector of South Africa, the system of separate development has had a "ceiling effect", tantamount to that of a caste system. Thus, for many years, blacks were unable to aspire to the very best available social services and education. Effectively, therefore, blacks were unable to promote themselves into occupations with correspondingly better income. They have therefore been entrenched into the lower social strata (again in its broadest sense). In addition to these economic differentials, the policy of homelands migration has fragmented families, resulting in further large differences in social strata between the race groups. The close relationship between race and social class in South Africa is demonstrated in Table 4 (i) below.

	UK	SA	% WHITES	% COLOURED	% BLACKS
CAPITALIST CLASS	5	4	11	0.6	0.5
MIDDLE CLASS	30	30	60	25	13
WORKING CLASS - SKILLED	38	11	23	13	5
SEMI-SKILLED	18	17	5	29	20
UNSKILLED	9	40	1	33	62

***TABLE 4 (i): RELATIONSHIP BETWEEN RACE AND CLASS IN SOUTH AFRICA²³⁷**

4.2.5 Social stratification as a scientific tool

Thus far we have examined the theories of stratification, in particular, social class. The question still remains as to how best to define social class as a scientific tool in order to investigate its relationship to lung function.

Various attempts have been made to divide populations into strata for research purposes, but all these proposed classifications have deficiencies. Historically, one of the first accepted classifications was that of the Registrar-General's classification^{229,238}, devised in Britain in 1911 to illustrate the different infant mortality patterns according to social class. The classification was based on employment (indicating the degree of skill involved in a job and, therefore, its status) and divided the population into five groups.

Class 1: capitalists, managers, scientists, artists, professionals.

Class 2: small shopkeepers, lower professionals, farmers.

Class 3: skilled labourers.

Class 4: semi-skilled labourers.

Class 5: unskilled labourers.

Difficulties with these divisions include the combination of groups of people with widely differing lifestyles and attitude and groups who share the same occupational title but, in reality, have little else in common.

Finally, the classification does not separate employers from employees. Over the years the system has been improved although the allocation of occupational groups to particular social class is still (albeit to a lesser degree) arbitrary. Since 1961 classifications have been refined to distinguish people in the same occupation, but with different levels of responsibility. These modifications, it has been argued, have been made according to empiric data and not any sociological theoretical system. An example of the classification system that emerged from this work²³⁰, is :

Non-manual	I	Professional occupations (for example doctors and lawyers)
	II	Managerial and lower professional occupations (for example sales managers and teachers)
	IIIN	Non-manual skilled occupations (for example clerks and shop assistants)
Manual	IIIM	Skilled manual occupations (for example bricklayers and underground coal miners)
	IV	Partly skilled occupations (for example bus conductors and postmen)
	V	Unskilled occupations (for example porters, ticket collectors and general labourers)

It is worth noting the major subdivision of manual and non-manual, which reflects the marked differences of "behaviour and aspirations" repeatedly observed between these two groups. The classification also allows for changing the order of occupations between categories according to perceived changes in their social status. It is important to realize that the ranking of particular occupations in terms of status is largely determined by the researchers, rather than the population at large. Attempts have been made to sample the population's opinions of the correct ordering, but these are themselves weakened by error of bias and precision²³⁰.

Using social class as a tool in research is fraught with difficulties. There is a range of classification systems, each with its own shortcomings and each subject to underlying controversies about the definition, identification and research utility of social class ranks. It is, however, generally agreed that one distinction has emerged that is clear cut, easily identified and possesses real value in sociological research: the division between manual and non-manual workers²³⁰. This division may be substantiated on three grounds - economic, normative and relational²³⁰. The most objective of these is a division by economic criteria, i.e. income of individuals. Although there is some overlap between the manual class and lower groups of the non-manual group in pay, there is a significant difference between these groups. Non-manual workers also tend to have better promotion opportunities, greater job security, year wage increments and a cleaner, quieter, less dangerous working environment. Senior staff may also have their income enhanced by the receipt of "perks" such as a company car, or low interest mortgage and medical aid. "Normative" criteria refer to the beliefs and values of the two groups which tends to be similar intragroup, but different intergroup. "Relational" factors refers to friendship patterns whereby people tend to socialise and marry within their own social class. These distinctions are modified in South Africa where the normative and relational factors are influenced by legislation which dictates the access that people of different races have to to housing, health, educational or social amenities.

Investigators have, in general, used classifications based on income levels or occupation as they are objective, readily distinguished, measured and their use has proved of value. Income is perhaps the most widely used indicator because there is a highly discriminant inequality between upper and lower groups and the disparity between incomes has become wider over time^{229,230,231}. Baldrige²²⁸ points out that "the source of social crisis is the fundamental maldistribution of the economic system with extremes of wealth and poverty, coupled with racial prejudice and political impotency of the people". It has been suggested that wealth is a much better indicator of social standing, as it reflects how money has passed from generation to generation. It is, however, impossibly difficult to ascertain²²⁹. Studies have shown that income is directly related to life expectancy^{228,229}. The greater the income the taller,

more healthy and better off the people are²²⁸. Inherent in this is the observation that money determines lifestyle: the higher the income the more services can be afforded.

Occupation is held by many to be the best indicator of social class as it correlates with education and income²⁴⁹. Occupation and income are not necessarily synonymous because some occupations may be highly rated on a status scale, but not reflected in their income (e.g. professors). It is generally accepted today that the division into manual and non-manual workers does reflect the best indicator of social class. Occupation is "the central institution" in industrial societies²³⁹. The link between occupational status and measures of ill health is proven²⁴⁰. It has been estimated that unemployment (the bottom end of the occupation scale) will be associated with premature death^{241,242}. Occupation has been correlated with maternal and infant mortality and with illness, even after controlling for lack of income and overcrowding^{240,243,244}. Morgan, in his recent authoritative paper on measuring social inequality, also indicates that occupation is the most sensitive indicator²⁴⁵.

A third indicator that is widely used is that of education. Education is regarded by many to be the main avenue to an occupation and therefore the opportunity to complete schooling is among the most important indicators²²⁷. Education is therefore seen as the key to occupational advancement and therefore to income. Schrier²³⁷ in a study done in Soweto, found that occupational roles are obtained primarily on the basis of educational attainment. The level of educational attainment in turn depends largely on the education and occupation of the head of household.

Other indicators have also been examined, such as place of residence, housing type, family, duration of residence and many others^{228,229,231,232}. These are the result of the three main indicators (cited above) and offer little additional benefit in analysis of social stratification and health. An alternative approach has been to utilise composite indices derived by the combination of indicators, e.g. education and income. These have also not been shown to be of any additional benefit. Socio-economic classification tends to vary from country to country²⁴⁶. It would therefore be essential that a

classification applicable to South Africa should be developed. The development of such a system is complicated by the lack of standardization with regard to the definition of variables and the absence of generally accepted social indicators²⁴⁷.

4.2.6 Social mobility

The suggestion that a black middle class had emerged in South Africa was one of the factors that initiated this study. This suggestion implies that a significant change in the social stratification of South Africa (and perhaps the western world) had occurred. Such a change is referred to as the phenomenon of social mobility.

Social mobility is the movement of individuals within the class structure²³⁰. Two measurements are used: first "intragenerational" mobility (an individual or group's current position compared to his position at an earlier point in his life) and second, "intergenerational" mobility (the comparison of an individual or group's position with the class position of his family, or usually father). Interest in social mobility centres around its indication of the degree of freedom of a society which allows people to be rewarded for their ability (a metrocratic society) as opposed to one in which class stricture is rigid (ascriptive).

Among the most important studies of social mobility have been one conducted in Britain by Glass²⁴⁸, in 1950. He found that although there was some movement between neighbouring classes (e.g. unskilled to more skilled jobs), there was insignificant movement across a greater range (e.g. unskilled to professional) when intergenerational mobility was studied. The biggest barrier found was that between the lower and upper dividing line (e.g. manual and non-manual). These findings clearly indicate the importance of parental class in determining the social class of their children. These findings were supported by a similar study which found that 60% of businessmen were themselves sons of successful businessmen²³⁰. Goldthorpe²⁴⁰, in the early 1970s, undertook a major social mobility study using more modern methodology. He noted two forms of mobility, absolute and relative. In absolute terms he found that a considerable portion of the higher social classes now come from the lower social backgrounds.

He found that 7% of the sons of unskilled manual workers had achieved high status and formed 12% of all those in the higher classes during early adulthood. However, he found that 25% of higher class individuals had parents with a similar class so that, in fact, 46% of the sons of those from the highest group are themselves in the same category, with another 20% going to slightly lower professions, but an insignificant number going into the lower classes. He thus concluded that the absolute chances of the sons of working class people entering the highest class are greater, but in relative terms, they stand no better chance than 25 years ago. Recent studies have, in fact, suggested that there has been no reduction in social class inequalities and that, if anything, there has been widening of the differences in social classes. Failure of lower classes to enter higher classes is linked to the growth in the number of jobs and not because of extinction of classes. Another fact that emerges is that people who are born to parents in higher classes, will retain their positions²³⁰.

In terms of functionalist theory, mobility occurs because people are distributed in the hierarchy according to their ability^{231,248}. Those who have the ability to perform the functionally most important jobs, are rewarded irrespective of their starting point. A demographic mechanism has been put forward which suggests that the reason for mobility is the formation of gaps opened up by the families produced by higher category families²³⁰. However, social changes are perhaps the most important causes of social mobility. The best example would be the industrialization of nations, leading to expansion of skilled and professional positions at the expense of unskilled positions. It is, however, important to realize that this growth in occupation has not been created by an associated real rise in income and living standards. Another important catalyst for mobility is the political motivation to ease the tension between social classes^{230,248} by allowing some upgrading of lower classes. By allowing elevation of some into the middle class, the collectivist efforts to improve the lot of the lower class as a whole is reduced. Also, the ability for the few elevated to enjoy better school education and status, entrenches established systems by inhibiting lower class attempts to organise collectively and act politically. Failure to rise in the ranks will therefore be ascribed to personal failings rather than the economic/political system. It has been demonstrated that in the USA and Britain minimal social mobility has been able to

maintain the status quo. These latter aspects may be highly relevant to the South African situation. A high rate of industrialization with technological advances has created a great number of middle and upper class jobs. The concurrent emigration of skilled and professional whites (Intra race relation) has further increased the number of these jobs available. These jobs have been filled by white and coloured women and black men^{229,230}. From the employer's viewpoint, workers from these groups have the advantage of being satisfied with lower incomes. Recently, the right for blacks to attend "white" universities, own property in peri-urban areas and occupy more senior jobs has stimulated blacks to rise in terms of income or occupational groups. This has been accompanied by an increase in living standards compared to their parental generation, but not necessarily to the same level as whites occupying the same income group.

4.2.7 Conclusion

Investigations involving the effects of social stratification require identification of indicators of social class. These indicators may be used to stratify the population into groups or to act as markers of social stratification.

Academic sociologists have no precise definition of class. The very idea of a "class structure" depends on the imposition of certain categories on a complex and constantly changing social world in accordance with the assumption and preconceptions of the analyst. There is also little in the way of well designed experiments to validate a particular set of socio-economic parameters. It would appear that the current concept of social stratification in modern societies deals with trends in distribution of income, social mobility and the overall shape of class structure rather than rigid social class structures. There is, however, little agreement as to how these concepts can be quantitated and tested for validity. There appears to be a need for a simple classification that could be applied to health surveys. At present, however, the choice of classification depends on the study objectives and the age and composition of the study population.

It is also important that the role race has on social stratification (or vice versa) should be investigated simultaneously in order that the relative influence of these related (if not identical) concepts may be explored. This has not previously been done in studies on lung function and became the major consideration during the analysis of the data in this study.

CHAPTER 5

5. SOCIAL STRATIFICATION FACTORS AND LUNG FUNCTION

5.1 INTRODUCTION

Repeated attempts to develop values of lung function have failed to produce values that have received universal acceptance. This is despite the excellent efforts to standardise the methodology and equipment. In order to explain the variation in normal values derived from different populations, several conclusions have been forwarded including "race". However investigators that find "racial" influences on lung function should ensure that other confounding factors have been excluded and that "race" has been clearly defined. A neglected set of confounding factors is the social stratification differences that exist between black and white race groups throughout the world. Few studies have objectively examined the contribution of social stratification status on normal lung function. It is the purpose of this chapter to examine the evidence which supports the notion that social stratification impinges on lung function.

5.2 SOCIAL STRATIFICATION AND HEALTH

To place the matter in its widest concept, the relationship between social stratification and other health parameters will briefly be reviewed. The connection between socio-economic status and general ill-health has been investigated for more than a century. Steinberg and Becklake⁹⁷, in their excellent review of the role of socio-economic factors in determining lung function, points out that during the 19th century Dr William Farr analysed the Registrar-General's report on deaths in Britain. It was postulated in this report that poverty and its attendant inadequacy of housing, nutrition, hygiene and clothing might contribute to the striking differences observed in mortality among men engaged in different occupations. The industrialization of countries such as Britain and the USA, has led to an overall drop in mortality rates. This provides indirect evidence for the link between economic status and health. Social class gradients do, however, still exist and examination of mortality and life expectancy likewise confirms a social class link. In South Africa mortality rates for the different race groups have demonstrated a

substantial difference; blacks tend to have the highest rate and whites the lowest²⁴³. Simkins has demonstrated the close link between social stratification factors and race in South Africa, so highlighting the close relationship of poverty and high mortality²⁵⁰. The argument between the proponents of racial and those of socio-economic influences on health parameters is also well highlighted by several controversies in the biomedical world. Growth standards, for childhood growth patterns, were developed in industrialized (so-called first world) countries from studies of white children. It was found that these standards were inappropriate when applied to black children in developing (third world) countries; the black children tended to be lower than the predicted height and height for age normal range. This led to the belief of an ethnically determined growth pattern. Graiter and Gentry²¹¹ recently demonstrated that the original growth standard described the growth patterns in children of upper social classes in several developing countries. Their findings demonstrate that the differences in childhood growth standards are explicable by social class differences and provides conclusive evidence that there should be one standard for all children. More recently, Richardson demonstrated a deterioration in nutritional status based on weight and height in South Africa, again providing evidence for the role of socio-economic factors^{251,252}. A recent study by Lieberman et al²⁵³ investigated the role of socio-economic and medical risk factors in the apparent racial discrepancy in neonatal mortality between black and white infants in the United States. They concluded that the racial difference in premature birth (and therefore infant mortality) is attributable to specific medical and socio-economic characteristics". The greater frequency of deaths amongst black infants, they point out, can be largely accounted for by the higher proportion of infants of low birth weight in the black group. In South Africa childhood mortality patterns in the different racial groups (and hence socio-economic groups) are consistent with these conclusions²⁴³.

The relationship between the general ill-health of children and the socio-economic status of their parents has also been demonstrated²⁵⁴. The precise nature of the relationship does not allow causation to be inferred, but is highly suggestive and stresses the need for more basic research on the social correlates of ill-health.

5.3 THE RELATIONSHIP BETWEEN SOCIAL STRATIFICATION AND LUNG FUNCTION

There are several possible links between socio-economic status and impaired lung function in adulthood. The first possibility is that the relationship is direct, i.e. the contaminants of less favourable socio-economic status in adult life lead directly to impaired lung function. These include more frequent lower respiratory illness, less easy access to medical care and exposures to higher levels of community and domestic air pollution, in addition and independent of any occupational exposure. Another possibility is that the relationship is indirect and attributable to childhood socio-economic status. Children of families from low socio-economic groups may suffer more frequent respiratory insults as a result of both infections and environmental pollution which affects lung growth and development and result in lowered lung function which persists into adulthood^{100,101}. A third possibility is that lower socio-economic class with its attendant poor nutrition may directly impair normal lung development and lead to impaired lung function in adulthood. It is important to realize that the effects of poor socio-economic class in childhood may persist in adulthood despite the upward social mobility of the individual. These questions will be further explored in the discussion chapter.

5.3.1 The relationship of respiratory ill-health and lung function social stratification factors

(a) Relationship of respiratory ill-health to social stratification factors in adults

The relationship between socio-economic factors and respiratory illness (as determined by the presence of respiratory symptoms and abnormal lung function) has been examined in several epidemiologic population-based studies. Several recent studies have demonstrated social class gradients in the prevalence of respiratory symptoms, in particular cough and sputum^{97,255}. The value of these studies is reduced by the widely differing methodology and criteria for diagnosing pathologic respiratory symptoms. Nevertheless, a nation-wide study conducted through the College of General Practitioners, using a standardized methodology confirmed these social gradients²⁵⁶. Occupation was the most widely used indicator of social class. Respiratory symptoms were found to be almost twice as common in the lower social classes. Although the investigators did not accurately adjust for smoking habits, they did not appear to differ greatly between the groups and thus may not have exerted a significant effect on

the findings. Social gradients in smoking habits in similar studies in the United States^{257,258,259} have complicated the interpretation of the results obtained. In the analysis of respiratory symptom prevalence by Higgins²⁵⁸, socio-economic parameters including occupation, income and education were found to have only a weak deleterious effect in comparison to the much greater effect of smoking. This study was conducted in a largely rural area (Tecumseh) in which the span of socio-economic levels was relatively small, compared with the British studies which included a much wider spectrum of socio-economic gradients. The influence of socio-economic factors on respiratory health status (including lung function) has been raised in several recent publications^{1-6,6}. The socio-economic profile in South Africa is complicated by the race-related political laws of apartheid. Race-linked legislation concerning where people live²⁵⁹, what jobs they may perform²⁶⁰ and different education systems, reinforces the disadvantaged situation black people find themselves in. Thus, the indicators of social class used in overseas studies are not directly applicable in South Africa.

(b) Relationship of lung function to social stratification factors in adults

The major population-based studies which examined the relationship of social stratification factors to lung function are summarised in Table 5 (i). Stebbings²⁵⁹ studied 410 non-smoking men. He demonstrated a 400 ml difference in FEV₁ between those with the highest and lowest socio-economic status based on occupation, income and education. He does not, however, comment of the prevalence of previous smokers and this may have influenced his results. Although his lung function testing did not conform to ATS standards, all subjects were tested in the same way, making intra-study comparisons valid. Lebowitz²⁵⁷, in his study of mixed smokers and non-smokers, demonstrated a negative relationship between income and educational status and FEV₁. This social gradient was still present when smoking habits were taken into account. In the regression analysis of lung function, however, no strong relationship was demonstrated with the inclusion of stratification indicators. Cohen²⁶³ also demonstrated greater abnormality rates for FEV₁, TLCO (diffusing capacity of the lungs for CO) and closing capacity in the lower social stratification groups. She used type of residence, as classified by census data, as her indicator of social stratification class. Higgins²⁵⁸ used income, education and

occupation as her indicator of social stratification class. She did not find any significant difference in lung function between the social groups not accounted for by the smoking gradation. The population he studied was composed of a very narrow socio-economic range, which might not have been a good population for critically evaluating these factors. Kaufman²⁶³ studied 556 men in a 12 year longitudinal study of workers in the Paris area. Social class, smoking and occupational exposure were all shown to be independently related to annual FEV₁ decline. Rasmussen²⁶⁴, in Denmark, in a work-based study of men in clean jobs demonstrated a negative relationship between FEV₁ (and maximal mid-expiratory flow rate, MMEF) and the number of years spent in residences without central heating. This study was particularly interesting in pointing to a relationship between poor dwelling conditions in childhood and adolescence and the development of impaired lung function in adult life. In a later study a negative relationship of FEV₁ to occupation group was demonstrated²⁶⁵.

(c) Social stratification influences on childhood respiratory health

The relationship between childhood events and adult lung function is central to the question of social stratification influences on lung function. It is likely that much of adult lung function is determined more by childhood socio-economic status than by adult status¹⁰¹. It is during childhood that most of lung growth occurs, being completed in the male by 25 years¹⁵³. It is possible that the growth rate of the lungs is also influenced by the clearly established effect of socio-economic influences on body growth rate of children²¹¹.

It has also been argued that childhood respiratory illness may affect respiratory development and therefore affect adult respiratory status^{100,101}. Social class gradients for respiratory illnesses have been reported among children in adolescence. Colley²⁶⁶ undertook an investigation of the urban and social origins of childhood bronchitis in England and Wales. They studied 10,000 children living in various urban and rural areas from families of wide-ranging socio-economic status. They demonstrated a two fold increase in the rates of cough and bronchitis in the lower two classes when compared with the

TABLE 5 (i): STUDIES IN WHICH SOCIAL STRATIFICATION INFLUENCES ON LUNG FUNCTION HAVE BEEN EXAMINED

AUTHOR		LOCATION		STUDY POPULATION				METHODOLOGY			FINDINGS	
NAME REF	NO.	SITE	YEAR PUB	NO. OF SUBJECTS (AGE RANGE)	POP BASE	DATA NON-ATTENDERS	SMOKING STATUS	NORMALITY SCREEN	PULMONARY FUNCTION TESTS	ATS STANDARDS	SOC STRAT INDICATOR	
Higgins 258	01	Michigan USA	1977	4699 (1626M M+F (20-74)	U/B	NS	Mixed	NS	Spirometry	No	Income Education Occupation	Negative relationship
Kaufmann 263	02	Paris France	1979	556M (30-54)	U/B	NS	Mixed	NS	Spirometry	No	Occupation	Increased rate of decline of FEV ₁ with age
Lebowitz 257	03	Arizona USA	1977	3485 M+F (7-70)	U/B	NS	Mixed	NS	Spirometry	No	Income Education Occupation Combination	Negative relationships to income and education
Rasmussen 264	04	Denmark	1978	218M (40-69)	U/B	NS	Mixed	NS	Spirometry	No	Household heating Place of residence	Negative relationship to household fuel pollution
Stebbing 259	05	Maryland USA	1971	410M (35-64)	U/B	NS	Non	NS	Spirometry	No	Combination score	Negative relationship

M = Males; F = Females; U = Urban based; NS = Not stated; ATS = American Thoracic Society

TABLE 5 (ii): STUDIES IN WHICH SOCIAL STRATIFICATION INFLUENCES ON LUNG FUNCTION HAVE BEEN EXAMINED: METHODOLOGY

AUTHOR	NO.	SOCIAL STRATIFICATION INDICATORS	TECHNIQUE	RACE EXAMINED	RELATIONSHIP OF LFT TO SES
Higgins	01	OCCUPATION White vs blue collar vs agriculture vs education 0-8 yrs vs 9-12 yrs vs college INCOME <5000 vs -9999 vs >10000	Questionnaire (Investigator developed) Lay Interviews	No	Negative relationship FEV1 to all indicators (but weaker than to smoking)
Stebbings	02				Improvement to regression equations
Kaufmann	03	OCCUPATION Managers; skilled manual; clerks; unskilled manual	Questionnaire (Investigator developed)	No	Negative relationship FEV1 decline to occupational group (but weaker than to smoking)

FEV = Forced vital capacity; FEV1 = Forced expiratory volume in 1 second

TABLE 5 (ii) (continued): STUDIES IN WHICH SOCIAL STRATIFICATION INFLUENCES ON LUNG FUNCTION HAVE BEEN EXAMINED: METHODOLOGY

AUTHOR	NO.	SOCIAL STRATIFICATION INDICATORS	TECHNIQUE	RACE EXAMINED	RELATIONSHIP OF LFT TO SES
Lebowitz	04	<p>INCOME <4000; 4- >7999, 8-14999; >15000</p> <p>EDUCATION 0-8; 9-11; 12; 13-15; 16+ yrs</p> <p>OCCUPATION Prof & semi prof; managers; skilled & semi skilled; unskilled manual</p> <p>RESIDENTIAL MOBILITY No. of moves in 2 years, social mobility, crowding and housing > 1.01 persons/rm</p> <p>Overall index</p>	Questionnaire (Investigator developed)	No	Negative relationship FEV1 income and education (but weak effect on regressions of lung function)
Rasmussen	05	<p>OCCUPATION Factory workers, blue or white collar and farmers</p>	NS	No	Negative relationship FEV1 and occupation

FEV = Forced vital capacity; FEV1 = Forced expiratory volume in 1 second

upper two classes. A similar correlation between illness rate and social class was also demonstrated in a study of black children in Baltimore, USA²⁶⁶.

(d) Social stratification influences on lung function in children

Several investigators have examined the relationship between lung functions in children and socio-economic factors. These studies have recently been reviewed⁹⁷. Holland²⁴⁸, in England, based socio-economic status on parental occupation, area of residence and family size. The socio-economic effect demonstrated was modest (3-5%) and occurred only in half the sub-groups examined. These results are not easy to interpret, since only the PEF_R (peak expiratory flow rate) was measured, differences in the components of the various age-sex groups studied and the failure to look at parental smoking habits. No information regarding the spread of socio-economic groups studied is given, so further detracting from the study. A similar study was undertaken recently by Vedal²⁶⁹ in the USA. In this study lung function was measured by spirometry using accepted methodology. Parental smoking habits were taken into account. Social stratification status was based on parental occupation and education. A socio-economic effect of 2% was found in FVC and FEF₁. In South Africa, Benatar²⁷⁰, pointed out that the low proportion of variance in pulmonary function in the FVC between different race groups suggests other determinants of lung function. He suggested that interactions between low social stratification grouping, malnutrition and disease may be responsible. In two other studies^{267,271} the socio-economic classification used was housing status. These studies found a poor relationship to lung function and in the Welsh study a reverse relationship was demonstrated. These studies used only one parameter, housing status, without giving detail as how housing is allocated in the areas studied. Thus, the relationship of housing status to socio-economic status is questionable and may explain the apparently anomalous results.

In the stronger studies reviewed above, a socio-economic gradient in respiratory illness and lung function has been demonstrated. This is true for both adults and children. It would therefore seem wise

to take socio-economic factors into account when measuring lung function. This would be particularly important in those studies concerned with establishing normal values.

5.5 SOCIAL STRATIFICATION INVESTIGATIONS IN SOUTH AFRICA

Social class as a confounding variable is particularly important in race comparisons of lung function owing to considerable association between social class and race in many societies, including South Africa²⁵⁰. There are a multitude of inter-related factors that attend the social stratification of an individual. Workers (e.g. blacks in South Africa) often live and work in industrial areas where the housing tends to be inferior and general environmental pollution is likely to result in obstructive lung disease. In South Africa the use of home fuels may also contribute to the general environmental pollution. Other factors include nutrition, vaccination, access to medical care, likelihood of severe childhood respiratory infections, and parental smoking habits. The inter-relationship of "race" and an individual's social stratification position has already been discussed (see Chapter 4).

To unravel these complex inter-relationships requires the study of sociologically stable populations whose stratification profiles are similar. It is also important that the investigators state their interpretation of "race" in order that the extent to which "race" and other stratification influences may be separated for the purposes of analysis.

One approach is to accept that both race and social stratification exist as two potentially different concepts. It would then be feasible to investigate the relative influences of race and social stratification on lung function directly by identifying three groups made up of a group of middle class blacks, another group of middle class whites and a group of low socio-economic blacks. The additional group of middle class whites would act as control for their black counterparts. This view is in agreement with that of Goodman who, in his study of the social differences in mortality rates for blacks and whites, suggested that the only way to unravel the confounding effects of socio-economic status and race was the study of a population in which there was substantial representation of all groups in the middle class category²⁷².

Although penetration into higher occupational groups is occurring in South Africa, this is very recent and the childhood social stratification status of present-day adults was probably homogenous within the black community. In addition, the phenomenon of polarisation is likely to be evident in South Africa. Blacks, irrespective of their income group, are still forced to live in areas and homes that are far inferior to those of their white counterparts.

The strength or weakness of any study on socio-economic factors influencing lung function hinges on a valid social class classification. The problem in South Africa is complicated further by the intimate relationship between politics, "race" and social stratification. Due to the migratory, unstable and fragmented nature of many black communities in South Africa, classification based on pure socio-economic indicators is likely to be tenuous.

The only currently available classification of note in South Africa is based on the analysis of occupation by race in two manpower surveys between 1969 and 1977²⁵⁰. With the emergence of black white-collar workers in South Africa²⁵⁰ it seemed possible to us that a more meaningful classification might be developed. This relatively new black social class does not span a full generation as yet and thus it was essential to evaluate childhood status in order that the interpretation of results could take social class factors during the formative years into account. The relatively new black middle class may not as yet enjoy a stable community and the resulting migration to and from rural areas may itself confound investigations into influence on pulmonary functions.

To study the impact of social stratification and race on lung functions it was felt that a relatively stable community may be found in the Johannesburg area where the greatest concentration of middle class blacks appear to be concentrated as a result of equal opportunity policies of large corporations. We proposed to obtain information concerning various aspects of social stratification during childhood and adulthood and to examine their relationship to lung function. It was realised that it would be necessary to establish indicators of social stratification due to the lack of data in this area. The next major problem

was how best to obtain social stratification information and pulmonary function data in the different groups. Three possible studies were considered:

- 1) a school-based study on children,
- 2) a work-based study and
- 3) a community-based study.

The strongest study plan most probably would have been the measurement of pulmonary function in a stable community fitting the criteria mentioned above. In addition to the problems already outlined with finding such a population, access to the community at a time of volatile political conflict, brought the feasibility of such a study into question. A school-based study, although tempting, with its theoretically "captive population" was the least favoured because it would not allow the subsidiary goal of establishing lung function normals for the working population to be achieved and there is also the problem of having to obtain socio-economic information from the childrens' parents. Thus a work-based study of individuals who live in a similar area appeared to be the best in terms of practicality, as well as being likely to yield sufficient data to test our hypothesis. The advantages of using the work based population chosen for this study will be outlined in the Methods chapter.

5.6 CONCLUSION

The influence of social stratification factors on various aspects of health has been well demonstrated in several areas of biologic research, including medicine. In addition, the relationship of these factors to respiratory health and pulmonary function has also been suggested. Investigations aiming to separate the influences of race and social stratification are complicated by the difficulties in quantitating both these concepts, as well as the controversies regarding the degree to which the two concepts overlap. It has to be accepted that such an investigation is unlikely to resolve the question satisfactorily for all scientists interested in this area of research, as the interpretation of results is almost certainly influenced by an individual's perception of race and social stratification. Nevertheless, the opportunity to shed light

on confounding influences that may erroneously have given rise to the current notion that racial factors influence lung functions, justifies the undertaking of such an investigation.

CHAPTER 6

6. AIMS, OBJECTIVES AND FEASIBILITY OF THIS INVESTIGATION

The aims, objectives and feasibility of this investigation are outlined in this chapter.

6.1 OBJECTIVES

To examine the relative influences that socio-economic and environmental factors, race and anthropometric factors have on lung function measurements of adults, we set out to conduct a study on carefully selected groups of adults. In carrying out the study, data regarding the spirometry of normal South African whites and blacks were to be gathered; with regard to blacks, the size of the study group was to be larger than any previously published study of normal, non-dust exposed blacks. It appeared likely that the data collected might prove to be more representative of black South Africans than the reference values currently used by several university and state laboratories.

6.2 AIMS

1. To test the hypothesis that socio-economic and environmental influences during childhood play a dominant role in the causation of lower spirometric (FVC and FEV₁) values that have been repeatedly demonstrated in blacks (compared to whites).
2. To gather spirometric (FVC and FEV₁) data and single breath gas transfer factor measurements in normal, non-dust exposed adult blacks and a comparable group of whites.
3. To develop, by means of accepted methods of statistical modelling, prediction equations for spirometry (FVC, FEV₁) and single breath gas transfer (TLC_{OSB}) of normal adult black and white South African males.

6.3 EFFORTS TO IDENTIFY A SUITABLE STUDY POPULATION

6.3.1 Identification of Study Population

(a) Introduction

In order to meet the aims of the project, it was recognized that at least three groups needed to be studied; (a) a middle class black community whose data and functions could be compared to (b) a similar white middle class population and (c) a lower socio-economic class black group. It was essential that all three groups shared a similar age and health profile. During the months March - July 1986, contact was established with community and health agencies, as well as business organisations in several cities in South Africa. Three major problems were immediately encountered:

1. A large enough group of middle class blacks could not easily be identified in South Africa,
2. The effect of the Group Areas Act appears to have resulted in black people of all economic groups living in similar environmental conditions. Therefore a community based study was not feasible because of the costliness involved in screening very many individuals in order to identify a sufficiently large group of black middle class men. Moreover, political violence in the black townships rendered a community-based survey vulnerable to foreclosure.
3. The hostile political atmosphere reflected in the schools boycott which was in full swing at the commencement of the survey in 1986, thus excluding the possibility of a school based study. The hostility also made access into communities difficult so also reducing the feasibility of a community based study.

The largest group of black middle income earners was identified in the Johannesburg. These people lived in one of two black townships situated in close proximity, namely Soweto and Alexandra townships. The expanding geography of this city has resulted in Alexandra Township being surrounded by white suburbs, while Soweto is on the outskirts of Johannesburg. Discussions were held with several community leaders, resulting in good support for the project. The physical dangers of working in these areas, however, precluded a community-based study.

A study of the ethnic composition of the major corporations in Johannesburg was then undertaken by consulting with the Personnel Managers of several companies. It became apparent that the profile of one of the country's largest banking groups (the First National Bank; formerly Barclays National Bank) satisfactorily matched the target population groups required for our project. Following several meetings with the management of the Bank, permission was granted for a study to be undertaken on the staff working in three of the Bank's main administrative buildings in the town centre.

(b) First National Bank (FNB)

The study was feasible because of the large number of blacks (500) occupying clerical or more senior jobs in the Bank. This situation has arisen following the introduction of a policy of "Africanisation" during the mid '70s. The policy, coordinated by a special section (Equal Opportunities Programme) is aimed at integrating blacks at all levels of the Bank²⁷³. The following are those attributes that have a bearing on this adoption of FNB employees as a study-group definition:

- a) the bank is an equal opportunities employer, irrespective of race, religion and sex, thus reducing the risk of selection bias due to these factors;
- b) the bank does not have any particular selection requirement with respect to physical attributes of its staff, and no pre-employment health screening is required, thus reducing the risk of selection bias influenced by physical attributes;
- c) the bank has a wide range of jobs, thus attracting people from most sectors of the population, thus reducing the risk of selection bias due to job category;
- d) working in a bank entails an atmosphere free of toxic inhalants of any kind, thus eliminating occupational lung diseases as a confounding factor;
- e) an active policy, entailing the employment, training and promotion of black staff (as a consequence of the equal opportunities programme), has resulted in one of the largest complements of black staff working in clerical or more senior positions in South Africa, thus a large enough black middle class group could be selected;

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- f) the Bank's three largest administrative buildings are situated within one kilometer of each other in the town centre, which made the survey relatively easy in practical terms;
 - g) the proximity of the bank to the largest urban collection of black people in South Africa (Soweto) has made the bank a popular place to seek employment; this meant that most of the black employees currently lived in a similar, well-defined environment;
 - h) the fragile political climate of the country made access to black populations in their communities very difficult, thus a work-based study capturing subjects representative of their population groups was the only form of epidemiological study deemed to be feasible during 1986/87;
 - i) the Bank's genuine commitments to their social responsibilities in South Africa was reflected in their supportiveness in all aspects of the surveys.

6.3.2 Feasibility Study

The feasibility of undertaking the proposed lung function survey using the workforce of the First National Bank was investigated during the period August 1987 - February 1988. The aim of this study was to establish:

1. the profile of the workforce with respect to age, race, sex, position in workforce and income;
2. the total number of potential subjects;
3. the number of people who would be willing to participate;
4. the basic demographic profile (with respect to place of birth, childhood environment and smoking habits) of the group.

The feasibility study was undertaken in three phases:

1. Barclaycard House survey.
2. Personnel list scrutiny.
3. Postal questionnaire.

1. Feasibility Studies: Barclaycard House Survey

The National Head Office and Regional Office of the Bank's card division, Barclaycard (now renamed First Card), is housed in Barclaycard Centre, Johannesburg. According to the Bank's management, a large number of clerical and more senior staff of all race groups were employed in this centre. Access to the personnel departmental files was granted by management and, once confidentiality had been assured, approval for a study was also received from staff representatives.

This survey had three main goals:

1. to establish the profile of the staff with respect to age and sex within each ethnic group,
2. the distribution of ethnic groups within the income groups and
3. obtaining information on home environment: where staff had been born and were currently living.

The data was obtained from the individual staff records with the assistance of a personnel officer. The survey revealed that the majority of staff were women of mixed colour (coloured) ethnicity. There were, however, a significant number of white and black staff in all income groups. Of the Blacks, 95% were men who all lived in urban Johannesburg; 50% in Soweto, 45% in Alexandra Township and 5% elsewhere. Ninety percent of the white staff and 48% of the black staff were still living in the same urban area where they were born. Fifty-two percent of blacks had been born in rural areas and had migrated to urban Johannesburg in their early adulthood. It was found that the rural born blacks were employed in the lower income jobs (cleaning and catering), while the urban born group were employed in higher income jobs.

On the basis of these data, it was concluded that the employees at Barclaycard House were likely to comprise a suitable study population which would include the three social stratification groups required. However, the survey would require far greater numbers (see Chapter 7: Sample size calculation). To this end permission was obtained to survey employees of all the Bank's main administration centres

situated in the central business district of Johannesburg, as well as the total black workforce of the Bank in greater Johannesburg. This was undertaken in the next phase of the feasibility study.

This was performed in 3 stages. All lists were produced by the computer service centre from personnel data stored on the Bank's mainframe computer.

- 1) A list of all black employees earning more than R8000/year, detailing age, current job title, current yearly income and place of work was initially examined. It was arbitrarily decided that a middle income earner was one who earned an income of between R9500 - R30000/year. If the assumption that a current middle class earner was likely to have been born into a middle class family were approximately correct, it seemed likely that a large enough group of middle class blacks could be studied. 180 blacks earned more than R9500/year, with only 25 of these being women. It was decided on the grounds of this encouraging information to proceed with the feasibility study.

The next step was to ascertain whether an equivalent group of white staff existed.

- 2) A list of all white staff earning more than R8000/year, but less than R30000/year, was scrutinised. It was felt that people in this income group might be of a similar socio-economic status as the black staff analysed in the first computer list. This investigation revealed that a group of white middle-income earning men (of sufficient size) similar to the black group did exist.
- 3) Personnel lists of all black and white male staff working in the Johannesburg area were then obtained. These lists detailed the age, position in workforce, place of work and number of years employed by the bank, and allowed identification of blacks in low income, non-clerical groups. It was decided at this stage that the final phase of the feasibility study was justified. It also became evident that the number of black (African) women employees was small, particularly in the middle

income group. This, together with the expected high costs of the project and limited time, led to the decision that women should be excluded from the study.

2. Feasibility Studies: Postal Questionnaire

A letter was drawn up, outlining the aim of the proposed survey, the motive for choosing the Bank's staff and an explanation which served to encourage the staff to participate in the survey (see Appendix I). The letter was accompanied by a questionnaire and self-addressed envelope (Appendix II). The purpose of the letter and questionnaire was to:

- 1) allow further analysis of age and race profiles (see results section);
- 2) obtain childhood environmental data;
- 3) obtain data regarding smoking habits with respect to current, previous and never smokers;
- 4) establish willingness to participate in the survey;
- 5) inform staff of the proposed project, and
- 6) provide assurances concerning the confidentiality of all information.

The questionnaire was distributed by the heads of each Section with the instruction that all recipients should return the questionnaire directly to the survey investigators in the self-addressed envelope provided. At that stage, some departments were excluded from participating by the Bank's management due to the pressure of their daily work schedule. The profile, as assessed by Chi squared tests, of the excluded group was essentially similar to the total population that was available for the study (see results section, Table 8 (i - v)).

An 84% reply was achieved. Non-respondents were contacted telephonically, in an attempt to gain a profile of this sub-population and their reasons for not participating. The profile of this group is also outlined in the results section (Table 8 (i - v)).

3. Feasibility Study: Conclusion

The feasibility of a project may be assessed in terms of these components: epidemiological, logistical, ethical²⁷⁴.

- 1) The proposed sample size was thought to be large enough to reproduce the previously reported differences in the lung volumes of white vs black men of lower socio-economic status.

The potential study population was likely to be composed of individuals representing different social stratification groups. It was therefore felt that the answer to the major research questions relating to racial determinants of social stratification could be answered. Of particular importance was the potentially adequate number of black men occupying middle social stratification positions as defined by income and occupation. Most individuals occupying middle social stratification positions appeared to have lived their entire lives in the same environment, although great differences in these environments existed between groups as defined by race. Black men occupying the lower social stratification positions were born and grew up in rural areas. This was felt to offer an important opportunity to investigate environmental influences on lung function.

The age distribution of the study population, 20 - 68 years, with a mean age of 40 years and median age of 35 years, would allow investigation of young adults with mature lungs.

A large percentage (40%) of the study population were lifetime never-smokers with a further 20% current non-smokers.

- 2) It was felt that the proposed project was logistically feasible. The Bank's commitment to assist in the survey, together with the obviously good motivation of all staff to participate, made it likely that the project could be completed in the allocated time.

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- 3) Ethical approval was obtained from the University of Cape Town's Ethics Committee. Further, confidentiality of information obtained was guaranteed by the agreement of the Bank's management to not require any information relating to the survey to be released to themselves.

6.4 CONCLUSION

The major aim of this investigation was to investigate the role of social stratification influences on FVC, FEV₁ and TLC_{0.5B}. The main purpose being to examine the relationship between "race" and other social stratification factors in causing the measurements of "blacks" to be lower than those of "whites". Although a population of adult males (black and white) occupying middle class occupations was identified, it was recognized that differences in social stratification as determined by indicators other than income, were likely to differ for the two race groups. Nevertheless, it was felt that the population identified was suitable and was certainly the "best" population possible at present in South Africa.

CHAPTER 7

7. METHODS

7.1 STUDY POPULATION

(a). Definition of study population

The definition of the study population was: all male employees of the First National Bank's administrative offices in central Johannesburg who agreed to participate in this study.

The above definition was subsequently modified in the following ways (motivations for these changes appear in the previous chapter):

1. It was decided to include all black male employees who held clerical or more senior jobs throughout the branches in the Johannesburg area.
2. Later during the study, it was decided to include senior black male administration staff working for South African Breweries Head Office.
3. The paucity of Asian and "coloured" male staff necessitated their exclusion from the study.

"Race" categories were defined according to the skin colour and facial appearance of individuals as stated in SA Population Act (No. 30) of 1950²⁷⁵:

- Black - a person who in appearance obviously is, or who is generally accepted as being, a member of any aboriginal race or tribe of Africa.
- White - a person who in appearance obviously is, or who is generally accepted as a white person.

The utilization of this terminology does not imply acceptance of this approach to stratify populations, but is necessary for purposes of this investigation.

(b) Sample Size

The tables derived by Davison et al²⁷⁶ were used to indicate the magnitude of difference in lung function measurement required given the size of a population group to ensure a 90% chance of detecting a difference in lung function measurement. In the estimation of the numbers of individuals required for each group, the following were considered:

- (i) size of the expected differences between the means,
- (ii) size of the variation expected,
- (iii) the relative numbers of subjects expected to be available in the groups.

7.2 FINAL ARRANGEMENTS OF PRIMARY SURVEY

Immediately following the postal questionnaire (see Chapter 4), posters outlining the objectives of the survey (see Appendix III) and indicating the venue and dates of the survey were placed on all relevant notice boards. The Bank made a large office on the 5th floor of Firstcard House available for the survey. The furnishings, computer hardware and stationery requirements were also provided by the Bank.

All interested respondents were then contacted telephonically and given appointments to attend the survey clinic. All subjects were reminded of their appointments on the preceding day by the research sister. A time limit of one and half hours for each subject was agreed to with the bank management. It was also agreed that subjects would have chest radiographs at the time of their interview and lung function tests. Where this was not possible subjects would return.

The author also gave seminars on various respiratory-related topics such as smoking and exercise when requested by staff associations to do so. An interview with the Bank's press officer, outlining the project and the important role the bank was playing the the survey, was granted to promote interest in the survey amongst the local population.

7.3 ETHICAL CONSIDERATIONS

The principal ethical consideration was the maintenance of confidentiality of all information pertaining to individual participants. Only the data obtained from the Personnel Department was discussed with the relevant senior bank officials. All other personal information obtained from the postal questionnaire and subsequent survey was kept in the strictest confidence. Participation in the survey was voluntary, gained by postal invitations, without prejudice to those who refused to participate. Local contact was established with worker representatives of both official and unofficial Union representatives.

The study was conducted with the collaboration of the Johannesburg Medical Officer of Health, the University of Witwatersrand Community Health Department, The Respiratory Clinics at JG Strijdom and Johannesburg General Hospitals and Department of Medicine of the University of Witwatersrand.

Ethical approval for the protocol to the study was obtained from the University of Cape Town's Medical School Ethics Committee.

7.4 PILOT STUDY

The objects of the pilot study were to:

- 1) Assess the motivation of staff to participate in this study.
- 2) Identify problems with the wording and the format of the questionnaire.
- 3) Test the most appropriate method of interviewing different language groups, viz direct verbal translations vs vernacular translated questionnaire.
- 4) Test the proposed method of floor management to ensure completion of all facets of the survey within the proposed time period.
- 5) Identify problems in the execution of the radiology survey.
- 6) Ongoing training of interviewers.

The pilot study was carried out over one week. During the fortnight prior to the survey interviewers were trained, the technologist acquainted with the apparatus and the clinic established. The methods of floor management, lung function testing, radiology survey and interviewing are discussed in the next section.

Changes that were made as a result of the pilot survey, are detailed in the same section.

The major consequences of the pilot study included the following:

- 1) Several defects in the questionnaire (the pilot questionnaire were identified, such as:
 - (i) repeat questions,
 - (ii) questions that should not be asked of all subjects, but included in a sub-routine,
 - (iii) ambiguous wording in certain questions,
 - (iv) cultural difficulties in interpretation of certain questions.
 - (v) incorrect proposed coding.
- 2) The need for a translator to be present to help in the interviews and lung function tests when interviewees were not fluent in English was revealed.
- 3) Difficulty was experienced in obtaining accurate ages from black subjects. It was decided to ask subjects their ages at next birthday and corroborate this with the age recorded by the personnel department's records. It was also anticipated at this stage that during analysis the data concerning age (viz age at next birthday, date of birth and personnel records age) should be carefully analyzed.
- 4) Differences between spirometry measured by Vitalograph and the Autolink apparatus was disclosed. The Autolink appeared to record volumes 3-4% greater than the Vitalograph. Since the

measurements were not interchangeable, Vitalograph as well as flow volume loop determinations on everyone were required.

- 5) The average time required to perform Vitalograph, flow-volume loop and Transfer factor in keeping with ATS requirements was shown to be 30 minutes. Thus, it was decided to perform spirometry first and then the Transfer Factor where time allowed.
- 6) The excellent quality of the chest radiographs was reassuring, except that there was a need to ensure that films were taken at maximum inspiration.
- 7) Logistically, the best format for the clinic was to have groups of 4-6 subjects present themselves at 3 hourly intervals. The order of interview/lung function tests/radiographs could not be randomly pre-determined. Thus, the order for each subject was decided by the sister, whose major constraints were to keep the technologist occupied and the time constraints of 1¹/₂ hours per subject.

Time did not permit all subjects who had been seen during the pilot study to return during the definitive survey. It was decided to repeat interviews on 10% of the pilot study group, using the final questionnaire format. No difference in recorded answers (as judged by interviewee's quicker understanding of questions) was identified, although the intelligibility of the questionnaire was clearly enhanced by the revisions. All of these subjects were requested to return for Vitalograph and repeat flow volume loop determinations. The questionnaire data, radiographs and lung functions obtained during the pilot study were included in the final analysis.

7.5 DATA COLLECTION

In order to fulfill the objectives of the study six discrete classes of information were required:

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- a) Identification data of each subject's current address, date of birth, age, marital status and ethnic language. These were obtained in section A of the survey questionnaire.
 - b) Social stratification histories: This was obtained for childhood (viz parental occupation, place of birth and childhood, sibling number and mortality, family housing status and childhood health and education) in section B of the survey questionnaire. Adult data was also obtained with regard to current position in the bank and income, as well as current accommodation. This was obtained in section C of the questionnaire. All this information was obtained during the course of an interview, except for income and bank grade, which was obtained from the personnel department as a computer printout.
 - c) Cardiorespiratory symptoms and previous cardiorespiratory pathology: This was obtained from the questionnaire. The ATS⁴⁵ respiratory questionnaire was used.
 - d) Smoking status: History was obtained from the survey questionnaire as to whether subjects or their families smoked cigarettes, cigars or other leaves. A "smoker" was defined as anyone who smoked more than 1 cigarette a day for more than 1 year. With regard to subjects who smoked, further information was obtained as to whether they smoked less than 10 per day, or more than 10 per day. If more than 10 cigarettes/day were smoked, the total number/day was determined. If they were previous smokers, the period of cessation was requested; only individuals who had stopped smoking 2 years ago were included in any analysis utilizing this group.
 - e) Lung physiology tests: These were done in the survey clinic, using ATS approved equipment and standardized procedures (described in Section 7.5 (b)). Subjects were studied without regard to the results of their questionnaire or radiograph. The order in which tests were done was allocated by use of random numbers determined daily prior to the clinic's opening.
 - f) Chest radiographs: these were taken at the municipal clinic using standard equipment (described in Section 7.4). Following a standardized procedure, postero-anterior and lateral radiographs were taken. These were done on the same day as the interview and lung function tests in most cases and within the week in the rest. All plates were reviewed by the author on the same day and subsequently by a radiologist and pulmonary physician separately, and then in consultation.

(a) The Questionnaire (see Appendix IV)

All the data was obtained from the lung function survey questionnaire. This was based on the ATS-2 questionnaire,⁴⁵ with additional sections to assess childhood socio-economic status and current socio-economic and environmental conditions. These latter questions were devised by ourselves after consultation with epidemiologists (Personal communications: Derek Yach, Prof Peter Bundred) and sociologists (Personal communications: Jonny Myers), who were knowledgeable in this field. The smoking section was also simplified so that subjects could be classified as current, previous or never smokers. Previous investigators have indicated that the reliability of smoking quantity in lung function studies is questionable and is usually not taken into account at analysis. It was felt that a simple distinction between light smokers (less than 10 cigarettes/day) and heavy smokers would be sufficient, although an estimate of total cigarettes smoked was also asked of the heavy smokers. In the case of previous smokers, the time period since cessation was recorded.

Once constructed, the questionnaire was tested initially on nursing sisters at Groote Schuur Hospital, subsequently on domestic staff, using translators and finally, in the field during a pilot study. The questionnaire was also submitted for evaluation by Dr Derek Yach of the Medical Research Council. The questionnaire was structured with clearly marked check-off slots; most questions were "closed questions" with a fixed alternative answer format.

Prior to the pilot study the questionnaire was translated into the regional black languages, Sotho and Zulu. The pilot study revealed several problems including:

- 1) the difficulty in using a literal translation, because of differences between the (academic) languages used in the the translation and the popular vernacular;
- 2) answer choices which were not appropriate to all interviewees (e.g. crushing of maize for urban dwellers, housing density related to nature of house and the interpretation of "siblings").

The final version of the questionnaire is shown in Appendix VI. The same translator was used for all subjects who were not fluent in English. The vernacular translations were not used, but the translator, who was fluent in all languages required, was instructed to use the same wording each time and to adhere to the format. That this was done was checked by both repeat interviews and reviewing the tape recordings as described in the section below.

The interviews were performed by trained, non-medical research assistants. Training was undertaken by the author utilising the method outlined by the American Thoracic Society⁴⁵. All interviews were tape recorded (in order to check on interview quality), except when the subjects were unwilling to allow the interviewer to do so (in 8 cases). A standardised interview technique was used. An interviewer was not permitted to deviate from the written wording of the questions. Each interview was conducted in precisely the same manner and the interviewer could not adapt questions for his specific situation or pursue statements to add to the data. Thus, the interviewers were required to read the questionnaire to the subjects and record their responses.

The completed interviews were immediately coded by the interviewer. The coding was then cross-checked by the second interviewer and the sister. All questionnaires were then checked by the author. Where appropriate, the latter used the tape recordings to confirm that the interviewing technique was being adhered to and that the data recorded was correct. Where errors of either omission or poor technique were encountered, this was demonstrated to the interviewer the next day. Interviewers were also encouraged to listen to each other's tape recordings and so encourage each other to adhere to the same technique and with the required enthusiasm.

Several sub-routines were included in the design of the project. These included a sample (15%) of interviews being repeated by the author and a further sample (20%) having their questionnaires completed by the author from the tape recording without reference to the original questionnaire. The

interviews handled in this manner were selected by use of the random number generator (described previously). The repeat interviews were done in the same session.

Two further validation checks were incorporated to allow comparison of answers with a "gold standard" (so called criterion-validation checks). Carboxyhaemoglobin was measured on a sample of subjects and BCG vaccination was examined for. Care was taken to ensure that interviewers and interviewees were unaware of the results and implications of these assessments.

(b) Lung Function Survey

1) Outline of tests performed and analysed

This survey was carried out in order to collect data on the lung function of adult men. The main aim of the survey was to collect data on common spirometric measurements (FVC, FEV₁, FEV₁/FVC %). These are the most widely used tests in epidemiology and have generated the largest literature regarding prediction values for subjects of different ages and ethnic groups. In keeping with modern surveys an automated computerized system (Autolink TTS^RMorgan) conforming to ATS standards was used. Although the Autolink computerized system consists of a well validated rolling seal spirometer, the automated software programme for the generation of flow volume loops was new and unvalidated at the time of commencement. Although unvalidated, the programme conformed to two well established theoretical considerations:

1. The sampling rate was greater than twice the frequency response desired by the system. The FVC manoeuvre being sampled at 2-5 millisecc intervals initially and thereafter at 10 mlsec intervals.
2. The resolution of the Analogue-Digital convertor was 1024 (or 10 "bit" device).

In addition to measuring flow and volume the programme was also capable of determining the largest value reached, e.g. in the forced expiratory manoeuvre, the loop with the largest FEV₁ and FVC recorded. Backward extrapolation was performed for the determination of the various maximum expiratory volumes in specific time intervals.

For the purposes of this survey only the FVC and FEV₁ were examined. The automated apparatus also provided instantaneous and mean flows (FEF 25-75%), but because of the inconsistency in their predicted values, the greater variability of these measurements in normal subjects and the absence of these measurements in most published surveys, these data will not be reported in this thesis. They will be stored and analysed in the future. The software allowed for the immediate correction of volumes according to the barometric pressure and temperature at the time of the test. These calculations were performed using the equations accepted by the ATS which were also the basis of the correction factors used for the correction of the Vitalograph functions.

Subsequent to the commencement of the study, and prior to the analysis of functions, the Autolink lung function system underwent stringent testing utilizing the computer generated wave patterns, as recommended by the ATS latest update on standardization and was found to be acceptable²⁷⁷.

In addition to the above discussed aspects, computerization offered several other advantages in this survey. The ability to organize, store and retrieve the large number of variables on a large number of subjects is vital. The ability to superimpose each attempt, as well as to examine the different attempts separately but on the same screen, makes selection of "best functions" much easier.

In order that the data could be compared with previous studies and be of benefit to industrial screening programs, a less sophisticated, but equally accurate (and acceptable), bellows spirometer (Vitalograph) was also used. The inclusion of the well established Vitalograph was also felt to offer an important internal validation check of functions measured by the new computerised system.

The measurement of single breath gas transfer (TLC_{CO_{SB}}) was included in the aims of this survey because normal values are based on relatively small surveys and because there is little information concerning the influences of social stratification (including race) on this measurement.

The determination of all lung volumes (TLC) was not one of the primary aims of this investigation. Measurements were made on a 10% sample of the study population (randomly selected prior to commencement of the study). These were performed to complete the data set of lung functions for normal adult males in South Africa and will be analysed in greater detail at a later stage.

2) Selection of Subjects

All subjects who agreed to participate in this survey underwent lung function testing, which was done prior to analysis of the questionnaire data and radiographs. Following the pilot study, all subjects performed spirometric measurements on both the Autolink and Vitalograph and, where time permitted, Transfer Test determinations. The order in which spirometric measurements were performed (starting with either Vitalograph or Autolink) was determined for each subject by generating random (from basic computer programme) numbers (between 1-820) and allocating the code 1 (indicating Autolink first) or 2 (indicating Vitalograph first) prior to the commencement of the survey. Transfer Test estimation was always done last. The first 100 numbers generated were also allocated the code T, indicating the need for total lung capacity (TLC) determinations. The code was assigned to the clerking sheet by the sister on the subject's arrival. Where time did not allow completion of all the tests, the subjects were asked to return for completion of their tests. When subjects returned, all the tests were repeated in the order they were allocated.

3) Selection of Equipment^{30,51,52}

Spirometry

For the purposes of this study two main pieces of equipment were used, namely:

1. Morgan Transfer Test Autolink (Autolink); dry rolling seal spirometer.
2. Vitalograph^R - S (Vitalograph); dry wedge bellow's linearized spirometer.

There is no doubt that the quality of the apparatus itself is "vital" to acquiring accurate test results⁵¹. We therefore ensured that the apparatus conformed to ATS requirements, thus to ensure that data would be

comparable "inter-laboratory" and "inter-time period". The ATS, as well as the Intermountain Thoracic Society (ITS) recommendations for spirometry, were adhered to and these recommendations are summarized in Table 7 (i) below, and compared with the features of the equipment used. In addition, computer software of the Autolink was certified to have met the ATS specifications by an independent laboratory²⁷⁷.

SPIROMETRY FVC/FEV ₁	ACCEPTED STANDARDS	SURVEY EQUIPMENT	
	ATS/ITS	*AUTOLINK TRANSFER TEST	**VITALOGRAPH
Range/Accuracy (BTPS L) Flow range (L/s) Time (s)	7 L ± 3% or 0.050 L 0 - 12 30 (FVC) 15 (FEV ₁)	12 L ± 2% OR 0.0501 0-12 30 (FVC) 15 (FEV ₁)	7.8 L ± 3% OR 0.050 0 - 7.8 NS NS
Resistance and back pressure cm H ₂ O L/s from zero to 12 L/s Time zero	< 1.5 Back extrapolation	< 0.2 Computational Back extrapolation	< 0.4 Back extrapolation (manual)
Calibration Computational software	3 L + 2 L (2+6 secs) 24 standard waveforms Independent laboratory	3 L + 2 L (2+6 secs) 24 standard wave forms	3 L + 2L (2+6 secs) N/A

ATS = American Thoracic Society; ITS = Intermountain Thoracic Society; NS = not stated; N/A = not applicable; * = Morgan Inc.; ** = Vitalograph^R Medical Instrumentation; L/S = litres/second

TABLE 7 (i): COMPARISON OF ATS AND ITS MINIMUM SPECIFICATIONS WITH THAT OF EQUIPMENT USED IN SURVEY

Quality control measures to check performance were carried out throughout the survey as recommended by both the ATS and ITS. These are described later in this chapter under the heading "Quality Control". In addition to the above attributes, the selection of the equipment was also influenced by the fact that basic components had been used in our laboratory for ten years. Thus, not only was the excellent quality of the apparatus well-known, but the technologist was very experienced in their use.

4) Methodology of the Lung Function Testing

The pulmonary function tests were done in the survey clinic by the same qualified, and very experienced, technologist (seconded to the survey by the Respiratory Clinic of Groote Schuur Hospital and University of Cape Town).

The same equipment was used throughout the survey. Prior to the commencement of the study, both pieces of equipment were certified as being accurate and in good working order. Forty-eight hours were allowed for stabilisation of the apparatus at the higher altitude prior to commencement of the pilot survey. Regular calibration checks were done as described under the heading "Quality Control". The temperature of the clinic was maintained as constant as possible and fluctuated around a mean of 24°C with a range of 20-28°C. Barometric pressure readings were obtained from a mercury barometer, its accuracy was confirmed by a leading barometer enthusiast (personal communications: Mr Jones) and by comparison with reports from the weather station at Jan Smuts International Airport. Barometric pressure (with an accuracy of ± 1 mmHg) and temperature readings (recorded with an accuracy of $\pm 1^\circ\text{C}$) were taken during the testing of each individual participant, as well as the beginning and end of each day when calibration checks were done.

Subjects were asked not to smoke for at least two hours prior to testing. Subjects who admitted to being smokers when checked by the nursing sister, were observed for at least 1 hour before being sent through for lung function testing.

(i) **Spirometric Measurements**

Lung function test results were reviewed by the author immediately after they were done in order to ensure that 3 acceptable traces had been obtained or that a sufficient attempt had been made to obtain 3 acceptable traces. The traces were reviewed again at the end of each day in order finally to assess their acceptability.

The maximum expiratory volumes (FVC, FEV₁) were measured by either Vitalograph or electronic dry rolling-seal spirometer (Autolink). In 75% of cases tests were performed on both apparatuses, but in the remainder, time allowed us to use only one apparatus. Subjects were carefully instructed in the performance of the FVC manoeuvre. Where necessary, the translator (who himself had performed the test without difficulty) was asked to explain our requirements to the subjects. Nose clips were used in all cases. Subjects were studied in a sitting position.

An acceptable test was one which met the criteria shown in the table below:

1. performed with a maximum inspiration, with a good start;
2. smooth continuous exhalation, with maximal effort;
3. without an unsatisfactory start of expiration; characterised by
 - (i) excessive hesitation,
 - (ii) false start or
 - (iii) extrapolated volume of greater than 5% of FVC or 0.100 L, whichever is greater;
4. without coughing, Valsava manoeuvre, early termination, a leak, or any obstruction.

A minimum of 5 acceptable forced expirations were required for completion of a test, although in a few (2%) cases 3 acceptable traces were accepted. Where a large variability in expiratory manoeuvres was experienced a maximum of 10, but usually 8, manoeuvres were attempted.^{15,51} During the pilot study many more attempts were made (up to 20), but it was found that the yield was no greater and, in many cases, fatigue resulted. Reproducibility of tests was also based on the current ATS recommendations that the largest FVC and second largest FVC from acceptable curves should not vary by more than 5% or 0.100L, whichever is greater. At the time of performing this study it was not clear whether the 5% referred to FVC or FEV₁ and FVC. It was, however, decided to follow the ITS suggestion that these criteria refer to FEV₁ and FVC. The correctness of this assumption has subsequently been confirmed in by the latest ATS statement⁵¹.

The maximum values of the forced expiratory volume in one second (FEV_1) and the forced vital capacity (FVC) were used for analysis. These two values were not necessarily taken from the same curve. Data were excluded from analysis if, after several attempts, acceptable traces could not be obtained and if, at the time of analysis, 3 reproducible traces could not be found.

All spirometric volumes were reported at body temperature, ambient barometric pressure and fully saturated with water vapour (BTPS). In the case of the Vitalograph the conversion was manual using the conversion factors suggested by the ITS for the temperature and barometric pressure at the time of the test.⁵² The software of the Autolink made the conversion automatically, provided that the ambient temperature and barometric pressure were entered for each test. The basis of this calculation is on the equation comparable to the method used in generating the BTPS functions for the Vitalograph.

(ii) Single breath gas transfer

Single breath gas transfer factor (TLCO) was measured by the breath holding technique of Meade et al using the Transfer test apparatus mounted on the Autolink unit. Volume accuracy was ensured by use of the same spirometer described above. Both gas analysers were able to measure the full range from zero to the upper limits with the appropriate accuracy. The helium meter (a thermal conductivity meter) was linear, but the CO analyser (infra-red carbon monoxide analyser) was non linear. The CO meter was linearized electronically. Both analysers were carefully calibrated and a calibration curve constructed for CO by the manufacturers. The calibration curve for both helium and CO were checked by the sequential gas dilution technique³⁰, both at the beginning and end of the survey. Calibration checks for span zero-upper gas limit were also done twice daily. The linearized output was linear within plus/minus 1% for the full scale range. The timing device of the apparatus was demonstrated to be correctly carried out by the computation routine. The deadspace for both the system gas and the alveolar sample is calculated by the manufacturers and was recalculated weekly, or whenever the absorbers were changed.

Guidelines for gas concentration had not been well standardized at the time of the study. The work of Gray and Crapo¹⁵⁰ and the recommendations of ITS and ATS available at the time were considered. It was decided to use the following concentrations: CO 0,30% (range 0.25 - 0.35%), He 14% and O₂ 21%. The actual concentration received was CO 0.29%, He 13.5% and O₂ 21.5%. These were felt to be acceptable. The concentrations were guaranteed by the manufacturers within 0.01% and confirmed by ourselves by use of a reference standard gas concentration. The question of our choice of O₂ concentration for testing at 1700 m altitude will be dealt with in the discussion section.

A group of individuals (composed of participants of the research team and their colleagues) was studied with 25% O₂ concentrations (recommended by Crapo¹⁵⁰) and the results correlated with a sub-group who had their transfer tests measured by using the same apparatus and the recommended gas concentrations at sea level and altitude 1700 m.

The Autolink's computation programme for executing the transfer test ensured that the inspired volume was at least 90% of the largest, previously measured vital capacity. A trace was only accepted if this volume was inhaled rapidly (in less than 2.5 seconds). If this goal was not attained, the test was automatically aborted. The washout volume was entered by the technologist using the following convention: 0.75 L if patient's vital capacity was greater than 2.0 L and 0.5.0 L if less than 2.0 L. The alveolar sample of 0.65 L was collected in less than 3 seconds. The breath hold time of 10 seconds was set by the computation programme.

Subjects were requested not to eat, drink alcohol or smoke for the two hours preceding their appointment. Since the transfer test was usually at the end of their testing, the non-smoking period was estimated to be to at least 3 hours. This also ensured that subjects were well rested at the time of undergoing the tests.

The tests were performed with the subjects in the upright seated position. The subject was instructed to breathe in maximally following a normal expiration to and then to relax against the closed valve. Following the breathhold period of ten seconds (determined by the computational program), the subject was asked to exhale briskly. Following a washout volume of 750 cc (if VC 2L or 500 cc if < 2L), the alveolar sample, 650 cc was automatically sampled.

For purposes of analysis an acceptable single breath determination was achieved if two tests conforming to the above requirements were within 10% or 3 ml CO (STEP) min⁻¹ mmHg⁻¹ whichever is larger. The mean of the two tests were recorded for analysis. Two acceptable tests were attempted on all subjects where time permitted. A maximum of 4 attempts was undertaken if this was necessary to achieve the required reproducibility. At least 5 minutes was allowed between each test with the subject remaining seated in between⁵¹.

The transfer factor was calculated by means of the Jones-Mead technique¹²⁸. The computation also allowed the DL/Va to be calculated immediately. A sample of 100 people who performed the test were selected by random numbers (generated by a basic random number generator) to repeat the test. Prior to the repeat testing a sample of venous blood was taken for haemoglobin and carboxy haemoglobin determinations. This investigation is discussed more fully in the results section.

(iii) Total lung capacity

Lung volumes were measured by the multiple breath helium-dilution technique using a closed circuit spirometer system to obtain residual volume and total lung capacity⁷⁵. The apparatus was prepared in accordance with the manufacturer's instructions. Prior to each study the spirometer was checked for leaks and the deadspace calculated using the Autolink's programme.

(iv) Quality control

The quality of the equipment used for data collection and reporting have been described above. The quality checks of the equipment's precision and accuracy during the survey were obtained by calibration checks. These may be divided into two main groups: biological and mechanical.

Biological calibration checks

A group of 6 people, including 4 doctors and two technologists, had their lung function measured several times during the survey. All of these individuals were healthy lifelong never-smokers. All these tests were performed by the survey technologist, with the exception of the tests done on herself. The latter functions were performed by the author. The author and survey technologist had their lung functions measured at least weekly (by each other) and sometimes more often. As an additional check both the author and a second biological calibration subject had their functions measured at an ATS conforming lung function laboratory (at JG Strydom Hospital, Johannesburg).

Mechanical calibration checks

Daily checks were done at the beginning and end of each day as well as intermittently during the day when either the suspicion of the technologist was raised, or when the number of subjects was greater than usual. The Autolink spirometer and Vitalograph were tested by injecting 3.0 L of room air from 2 calibrated syringes at least twice, initially fast (in 2 seconds) and then slowly (in 6 seconds). The procedure was repeated using a 1.0 L syringe. The Autolink allows both the spirometer and data processing unit to be tested independently. This feature is important in validating the computation programme. On a weekly basis the spirometer was checked for leaks by inducing a constant positive pressure with the spirometer outlets occluded and recording the spirometer position for at least 2 minutes. No observable leak was acceptable. The test mode of the Autolink programme was also checked weekly by inducing a flow volume curve using the 3 L syringe and computing the FVC adjusted for the ambient temperature and barometric pressure.

The gas analyser calibration was tested both at the beginning and end of the survey to confirm linearity. In addition, the zero reading and upper reading were checked at the start and end of each day. The gas concentrations were also checked against identical analysers known to be accurate (by use of standard gas cylinders) on two occasions.

(c) Other Data

1) Anthropometric data were collected by an experienced nursing sister. The data collected included:

- i) standing height,
- ii) sitting height,
- iii) chest circumference, and
- iv) weight.

(i) Standing height was measured using a tape measure affixed to a wall and a set square to ensure accuracy. Care was taken to ensure heels, shoulder blades and occiput were positioned against the wall. All subjects were measured barefoot. The measurement was rounded off to the nearest 0.5 cm.

(ii) Sitting height was measured using the same tape measure and set square. The subject was seated on a hard-backed, wooden chair. The measurement was accurate to the nearest 0.5 cm. The height of the seat from the ground was subtracted during analysis to give the sitting height.

(iii) Chest circumference was measured at end expiration using the point of widest diameter. The measurement was made accurate to the nearest 0.5 cm. Patients with gross kyphosis or scoliosis or stigmata of previous trauma and chest operations were not measured.

-
- (iv) Weight was measured to the nearest 0.5 kg. Subjects were measured with their shoes and heavy clothing removed. All subjects were measured using the same spring-balance scale. The scale was calibrated every day, using both a 10 kg weight and a "biological calibration" (the Author).
- 2) The presence of a BCG scar was also noted by the sister and recorded as being either present, absent or not clear. This observation was done surreptitiously so as not to bias the subject during the interview, during which questions about vaccination were asked.
- 3) Haemoglobin and carboxy haemoglobin measurement were made on the group of subjects (10%) brought back for repeat functions. (The rationale for this group and its selection are outlined in the section dealing with quality control). Permission to include this aspect of the survey was received from the University of Cape Town Ethics Committee in order to strengthen the transfer test data and validate the smoking histories. The blood was taken by the nursing sister and analysed using an ABC-3 (Medical Products) blood analyser. Haemoglobin determinations were also made by the Haematology Laboratory at JG Strijdom Hospital, Johannesburg.

The quality of standing height, sitting height and weight measurements was checked daily by measuring and weighing by the author. This "calibration" exercise was done to ensure standard measuring positions and techniques.

(d) Chest Radiograph Survey

All subjects who agreed to participate in radiographic study were transported to the municipal clinic by the survey driver. Although it was decided prior to the survey to exempt those men who in the year preceding the study had had a chest radiograph performed, 95% subjects agreed to participate. The radiograph reports, with or without the radiographs, of the remaining subjects were reviewed by the author.

Postero-anterior and lateral radiographs were taken using a Phillips 300 X-ray generator. Films were taken with a relatively high kilo voltage (110 - 120 hv) technique and a moving grid. The films were developed immediately in a 3 MXP 510C automated processor. Chronix Protea radiographs were used throughout the survey. The films were checked for technical quality by the radiographer before each man left the clinic; if necessary, a repeat film was made. 92.5% of all radiographs were performed by the same, highly experienced and qualified radiographer. Of the remaining 8%, 6% were performed by the Chief Municipal Radiographer and 2% by a locum, who was also a qualified radiographer. The main radiographer was proficient in the home language of the majority of black subjects, her own home language being that of the commonest black group, that of Zulu.

Individual films were read by the author within 48 hours, in order to identify cases requiring clinical intervention (e.g. tuberculosis, bronchiectasis, cardiac failure, carcinoma, etc.) and to check the quality of the films. Abnormal features were discussed with the chest unit at the local medical school, University of Witwatersrand, J.G. Strijdom Hospital and Johannesburg General Hospital; if any abnormality requiring intervention or further investigation was identified, this was pursued with the individual concerned.

All the radiographs were reviewed by a consultant radiologist at Groote Schuur Hospital (Dr H Goodman) at regular intervals during the survey. The aim of this review was to examine the plates carefully for technique and pathology. Where either problem was encountered the information was relayed to the author and pursued in the relevant manner.

The radiographs were also reviewed by Dr SJ Louw (the supervisor of this project) and classified according to a fixed protocol for analysis purposes:

1. = Normal chest radiograph.
2. = Technically imperfect/poor inspiratory films (anterior end of 6th rib not showing on right).

-
3. = Hyperinflation (7th rib anterior; < 1 cm lateral).
 4. = Hyperinflation (7th rib anterior; 2 cm lateral).
 5. = Local volume loss - displacement of lung fissure, heart, mediastinum, trachea, diaphragm or thoracic cage deformity or extensive pleural disease).
 6. = Cardiac failure.
 7. = Interstitial disease.
 8. = Local disease - active tuberculosis
 - bronchiectasis.
 9. = Calcific foci - no volume loss.

Where two classifications were applicable, the radiograph was classified by means of two digit code using the digit corresponding to the most likely, or correct, classification and the second digit applicable to the secondary classification category.

Viz: 2/1 = technically imperfect but in course of normal clinical practice a normal chest radiograph.

 2/5 = technically imperfect but suggestion of loss of volume.

 5/2 = loss of volume is present/radiograph just meets minimal technical requirements.

The radiographs were read during 4 sittings over a 5-day period. During the reading period, the reader was unaware of the outcome of either the questionnaire or lung function test in each case.

7.6 CLINICAL FOLLOW-UP

A letter thanking the individual for participating and giving the results of the lung function test and chest radiograph was sent to each subject. Where requested, the results were sent to the general practitioner concerned. Cases in whom pathology were identified, the individual was also contacted telephonically and an appointment given in order to discuss the findings and to plan further investigation and follow-up.

Where appropriate, the individual was referred to the chest unit of Wits University. Alternatively, follow-up was undertaken by the person's general practitioner.

7.7 STATISTICAL ANALYSIS

1. General

Lung function data were entered manually on coding sheets which were then, like the coded questionnaire data, entered onto the computer by professional data punchers. This procedure was checked by means of simultaneous duplicate entry and computer verification, as well as by manual verification. Missing data, which resulted from subjects not being able to answer or complete the question, were entered as blank spaces. Where questions did not apply, this was entered as a 0. In all cases missing data resulted in the subject being excluded from the relevant analysis.

Data analysis was accomplished using an IBM computer, located at the Medical Research Council in Cape Town, South Africa. The SAS²⁷⁸ and BMDP²⁷⁹ packages were used. Descriptive statistics and frequency tables are presented for all subjects who entered the trial, as well as for the "normal" subgroup. Descriptive statistics consist of means and standard deviations where data is normally distributed, and medians where data is not normally distributed. The quality of the questionnaires and interview were tested by calculating the number of cases for whom the information obtained in the main interview differed from information obtained in the repeat interview or from the tape recorded answers. The relationship of social stratification indicators was assessed by using the Kappa statistic²⁸¹.

Comparison of subgroups with respect to categorical variables was done using χ^2 or Fisher's exact test when χ^2 was not appropriate because of small frequencies. Comparison of subgroups with respect to continuous variables was done using t-tests, or median tests where the data was not normally distributed.

The data for each subject was screened to identify "normal cases". A "normal" subject was defined as a lifetime non-smoker, with no history of cough, sputum production, wheeze, shortness of breath, significant

infection, history of asthma, chronic bronchitis, emphysema, bronchiectasis, cardiac disease or abnormal radiograph.

Multiple linear regression equations for FEV_1 , FVC, $TLCOS_B$ were obtained using anthropometric data, social class indicators and race as independent variables. The goal of the regression analysis was to determine the best prediction equations. The criterion used for the selection of regression equations, therefore, was Mallows' CP^{280} statistic, which estimates the mean square error of prediction of a given model. The best equation out of all possible prediction equations was selected using BMDP9R. The best equation in terms of the CP criterion is the equation with the lowest CP value. Equations with CP values approximately equal to the number of parameters fitted, represent adequate models. Although the R^2 statistic did not play a role in the selection of the best regression equation, R^2 values are provided in the Results Section for the sake of comparison with other research. Observations were investigated in terms of standardized residual and Cook's distance to determine whether there were any influential outliers which had to be excluded from the analysis. Except for the one case stated in the Total Lung Capacity Results section, no points were found which had to be excluded.

Lung function values (FVC, FEV_1 and $TLCOS_B$) were compared between different social stratification groups, using analysis of covariance, adjusting for anthropometric measurements and age. The different social stratification groups were adjusted to the mean values of the independent variables. To investigate the relationship between smoking, race, age group and place of birth a linear log was used.

2. Methodology of social stratification analysis

Indicators of social stratification were identified as follows:

1. An authoritative researcher in this field was consulted, namely Dr Johnny Myers, Director of the Industrial Health Research Group, Department of Social Sciences, University of Cape Town. Attempts to establish contact with other investigators were unfortunately unsuccessful.
2. An extensive review of the sociological literature regarding social stratification and its classification was undertaken. This was outlined in Chapter 4.

3. Review of the medical literature relating to social stratification with reference to health and in particular to lung function and health. This too is outlined in Chapter 4.
4. Following the above procedures questions were constructed with the aim of investigating the relationship between social stratification and lung function. (See Appendix VI).

The questions were divided into two sections:

- (a) childhood data (based on family characteristics), and
- (b) adulthood data.

Questions were constructed to explore the following groups of likely social stratification categories:

1. "Race" group - as defined by skin colour (Q 7) and home language (Q 8)
 2. Place of birth and area of childhood (Q 12)
 3. Household income (Q 15 and Q RRR)
 4. Family size (Q 22)
 5. Childhood housing conditions including area of residence (Q 13), type of housing (Q 25), home ownership (Q 24), housing size (Q 27), household environment (Q 28).
 6. Childhood health resources including medical services, utilisation and availability (Q 23).
 7. Highest educational level attained. (Q 31)
 8. Current income, as well as wealth and number of dependants (ex personnel lists).
 9. Current position in the workforce (ex personnel lists).
 10. Current housing conditions, including home ownership (Q 68), type of housing (Q 69), home environment (Q 70), area of residence and permanency of residence (Q65 - 67).
5. Prior to analysis, with the availability of greater insight into social stratification and the strength and weakness of our approach, it was decided to identify those items which were most likely to be indicators of social stratification, these were termed PRESUMPTIVE INDICATORS.

The presumptive indicators were split apriori into 2 categories, thought to be indicative of high and low social stratification. The point of division being based on both currently accepted guidelines in the literature, as well as anticipated sensitive demarcators of social stratification. The indicators and their categories are listed below in the order in which they were anticipated to be indicators of social stratification.

A. CHILDHOOD PRESUMPTIVE INDICATORS

1. Race group (as defined by skin colour)

high = white

low = black

2. Place of birth

high = urban (defined as living or situated in a city or town)

low = rural (defined as living or situated in country)

3. Father's occupation group (see Appendix vi)

high = non-manual (grades 1-7 Barclays code adopted Simkins scale²⁵⁰)

low = manual (grades 8-10 Barclays code adopted Simkins scale)

4. School education

high = \geq std 9 (allowed entry into management training programmes)

low = \leq std 8

5. Number of siblings

high = \leq 3

low = \geq 4

6. Sibling death (from natural causes under the age of 15 years)

high = none

low = \leq 1

7. Housing type (as defined by construction material)

high = brick and mortar

low = natural elements

-
8. Household environment (as influenced by fuel source)
high = electricity
low = wood, coal, coke or dung

The remainder of the questions relating to childhood social stratification were termed possible indicators and are listed in Table 8 (viii) in the order in which they were thought to be of value as indicators of social class.

The same approach was used for the adult social stratification indicators. Those indicators identified as being **presumptive adult indicators** were as follows:

1. Income (as defined by pay cheque not including perks)
high = > R10,000 per annum
low = < R10,000 per annum
2. Occupation (as defined by job grades and their descriptions in the Bank's management)
high = junior and senior administration
low = labourers/catering (manual)/security guards
3. Number of dependants (defined as number of people relying on wage earner for total financial support)
high = ≤ 4 individuals
low = ≥ 5 individuals
4. Home ownership
high = own (own home totally or paying off)
low = rent (private or public owned)

The remainder of the questions relating to social stratification were regarded as **possible indicators**.

This prior identification of **presumptive indicators** is more valid for hypothesis testing than the alternative approach, an examination of all the potential indicators, in the hypothesis testing procedure at analysis. This will be given further consideration in the discussion.

Analysis to assess the validity of presumptive indicators

In order to assess the validity of our "presumptive" indicators as being capable of identifying socio-economic class, the following approach was used:

- (a) The relationship of each indicator to indicators that have been used by previous authors, including father's occupation, education, housing, childhood mortality, number of siblings, current income, occupation and housing was tested. These indicators were all included in the list of **presumptive indicators** described in the previous section. In addition, "race" and place of birth, fuel source (childhood and adult) and number of dependants were examined. The relationship between each indicator and the other presumptive indicators was investigated by calculating the agreement beyond chance using the Kappa statistic. The Kappa statistic is most often applied when calculating interrater agreement, but can be used to calculate concordance between any categorical ratings. If agreement between two ratings or, in this case, two indicators of social stratification, is high the two indicators probably do in fact reflect social stratification. On the other hand, if supposed indicators of social stratification do not agree, then the usefulness of the indicators is limited. The values of the Kappa statistic can be classified as follows:

$K = 0-0.3$ weak relationship (may be the result of chance);

$K = 0.4-0.6$ strong relationship;

$K = \geq 0.7$ exceptionally strong relationship.

The above analysis was done, separately for the childhood indicators (indicative of our study population's social stratification position during childhood) and the adult indicators (indicative of current social stratification position). In addition, the relationship between childhood and adult

indicators was also examined. From the above analysis it was expected that the best individual indicators (i.e. those who agree with the various other possible indicators and thus reflects various aspects of social stratification) might be identifiable.

(b) Composite indicators were proposed for

(a) childhood: SOCEC

SOCEC: Place of birth (urban/rural) + father's occupation + no. siblings + sibs died + house type

High SOCEC: 3 or more of components being high category for each indicator.

Low SOCEC: 3 or more components being low category for each indicator.

and

(b) adulthood ADEC.

ADEC: Income + position in workforce + number of dependants + home fuel + home ownership

High ADEC: 3 or more components being high category for each indicator.

Low ADEC: 3 or more components being low category for each indicator.

The validity of these composite indicators was explored using the approach described for individual indicators.

(c) Once the best indicators had been identified (those with the highest agreement with other indicators), the next step was to examine the patterns of social stratification within our study population, with particular reference to the identification of these sub-groups, viz a high white group, a comparable black high group and a low black group.

The investigation was done by first dividing the populations into their "race" groups. The Blacks were then split into the two socio-economic groups, using the best indicators for both childhood

and adult status and examining their relationship to accepted markers of social stratification using the same method described above.

- (d) Birth and childhood in an urban or rural area was expected to be an important marker of social stratification. To explore this relationship the population was divided into 3 groups, viz white urban, black urban and black rural, and the relationship of these groups was explored relative to the other probable indicators of social stratification by means of χ^2 or Fisher's exact test. This was done in order to determine whether the birth place (urban and rural) exerted an effect on social stratification as judged by classical indicators such as income (father's and current), education level, housing and family size and death rates, as well as to examine the difference between white urban and black urban born individuals with respect to social stratification.

3. Analysis of influence of social stratification and anthropometric factors on lung function

In order to investigate the role of social stratification indicators on lung function, the following approach was adopted.

1. All subsets linear regression, using the BMDP package was employed.
2. The dependent variables
 - (i) FVC A/L (A/L = Autolink apparatus,)
 - (ii) FEV₁ A/L
 - (iii) FVC V/G (V/G = Vitalograph apparatus)and
 - (iv) FEV₁ V/G were analysed.

It was decided to examine the functions obtained from the two spirometers separately, because

- (a) it was noted during the pilot and main survey that the values of volumes measured by the two apparatuses differed systematically
- (b) comparison with earlier published studies which had used the Vitalograph should be examined.

-
3. The independent variables were divided into the following groups:
 1. Generally accepted anthropometric measurements including:
 - (i) standing height,
 - (ii) age and
 - (iii) weight.
 2. Possible anthropometric measurements reflecting "racial" differences including:
 - (i) sitting height and
 - (ii) sitting height/standing height ratio.
 3. Best social stratification indicators as identified by Kappa analysis.
 4. "Race" group as defined by skin colour (the usual criterion used in lung function surveys) was, for the purposes of the regression analysis, regarded as a separate variable.

"Race", thus defined, may be viewed to be an indicator of social stratification rather than of genetic difference (see Chapter 4 for a detailed discussion of this fundamental issue). For this reason it was included in the analysis of social indicators as described above.

CHAPTER 8

8. RESULTS

8.1 RESPONSE RATES

The identification of potential subjects, as described in Chapter 6, was made possible by the accurate identification details contained in the personnel records. Initially, the Bank's management agreed that all the black and white men working in the Bank's administration buildings, as well as black men employed in any of the branches throughout the greater Johannesburg area, earning in excess of R9000 per annum could participate in the survey. At the commencement of the postal questionnaire, however, 187 were prevented by management from entering the study because of anticipated work pressure.

The potential participants of the study therefore comprised the remaining 1005 men working in the above stated work places. The postal questionnaire was distributed by the research team to each of these men via their section heads. One hundred and sixty eight men (16.7%) did not respond to the postal questionnaire, while 5 (0.5%) refused to participate in the survey. Eight hundred and twenty seven (82.3%) men agreed to participate in all respects of the study and a further five (0.6%) agreed to participate in the lung function survey, but refused to participate in the radiological survey. During the survey 38 black men were not allowed to participate by their section head due to apparent work commitments, despite their willingness to do so. These men all earned in excess of R13200 per annum. Consequently, twenty men, who made up the total number of black employees earning R13200 or more in the head office of South African Breweries, were invited to replace some of this lost group. These men were considered to occupy a similar social stratification position as equivalent wage earners at the Bank. South African Breweries also has an active policy of black employment similar to the Bank's. Four of these men were unable to participate due to unforeseen work pressures or leave and 2 men refused to participate on arrival at the survey clinic.

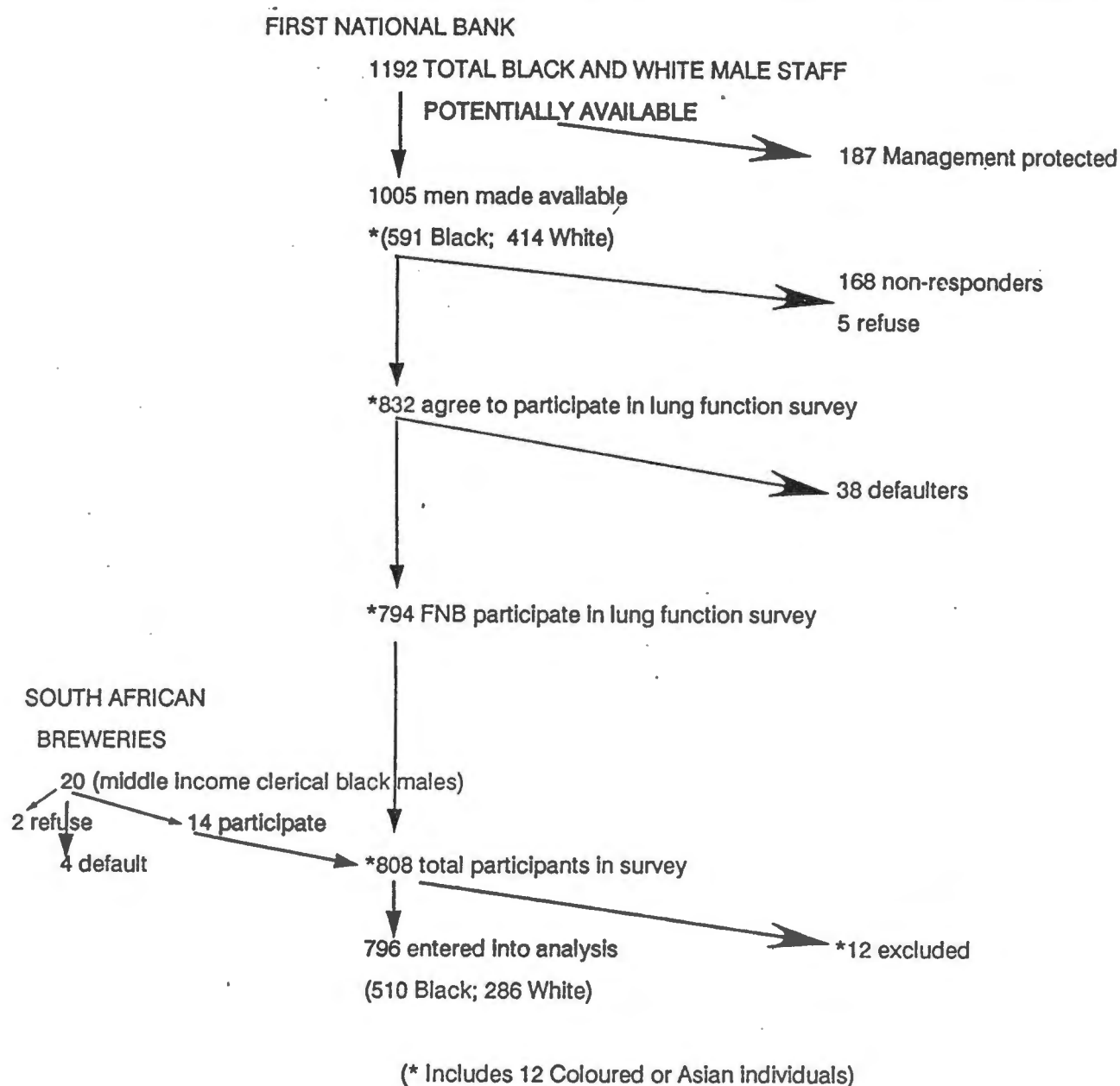


Fig 8 (i): FLOW DIAGRAM - SURVEY POPULATION

Eight hundred and eight men participated in the survey. Ten of the men who responded positively to the postal questionnaire and participated in the survey were of mixed blood and two of Asian extraction. They were not included in the analysis. Thus, 496 of 591 (85.7%) black and 286 of 414 (69.1%) white men working for the bank participated in the survey.

8.2 COMPARISON OF NON-PARTICIPANTS WITH PARTICIPANTS

There were four main groups of non-participants, those made ineligible by the Bank's management due to work pressure (management protected), those who failed to respond (non-responders), those who initially agreed to participate but failed to do so during the survey (defaulters) and a few (5) who refused to participate (refusers). The availability of details of age, race and income from the personnel department on all these men, and the additional information of place of birth and smoking history (obtained in the postal questionnaire) made it possible to construct descriptive tables of the men who could not be surveyed, for comparisons with those who were surveyed. Thus, possible sources of selection bias could be examined. In the case of non-responders and defaulters, telephonic or personal interviews were undertaken in order to ascertain smoking habits, and the reasons for not wishing to participate. Contact was established with 159 out of this group of 206 (77%). The small number of refusals, 5 (0.5%), is insignificant and highly unlikely to introduce a bias, and so were not analysed further.

Age Distribution

The non-participants and participants had similar age distribution.

GROUP	TOTAL NO.	MEAN AGE (YRS)	AGE GROUP (YEARS) NUMBER (PERCENT OF GROUPS)				
			<24	25-34	35-44	45-54	>55
Mx protected*	187	38.24	0	56(30)	78(42)	34(18)	19(10)
Non-responders	168	41.26	6(4)	42(25)	71(42)	37(22)	12(7)
Defaulters	42	38.42	4(10)	13(31)	16(38)	8(19)	1(2)
Participants	796	40.10	39(5)	213(28)	278(36)	162(21)	81(10)

* Mx protected: men prevented from participating by management.

TABLE 8 (i): AGE DISTRIBUTION: PARTICIPANTS AND NON-PARTICIPANTS

Race Distribution

The majority of men who were either protected from participation or non-responders were "white". The majority of defaulters were "black" of whom most had been prevented from participation by their section

heads. Several presented themselves despite this and were included in the analysis.

GROUP	TOTAL NO. OF MEN	RACE GROUP NUMBER (PERCENT OF GROUP)		
		BLACK	WHITE	OTHER
Mx protected*	187	3 (1.6)	178 (95.7)	6 (3.2)
Non-responders	168	30 (17.7)	136 (80.9)	2 (1.2)
Defaulters	42	35 (83.3)	7 (16.7)	-
Participants	808	510 (63.1)	286 (35.4)	12 (1.5)

* Mx protected: men prevented from participating by management.

TABLE 8 (ii): RACE DISTRIBUTION: PARTICIPANTS AND NON-PARTICIPANTS

Childhood Background

This information was only available for the group who defaulted. Using place of birth (urban vs rural) as an indicator for social stratification, the group compared as shown in Table 8 (iii). Place of birth was shown subsequently to be a good reflector of social stratification (see section 8). It may be seen that the major difference between the participants and defaulters was the proportion who were born in urban areas. The total number of defaulters, however, was not large.

GROUP	PLACE OF BIRTH NUMBER (PERCENT OF GROUP)	
	URBAN	RURAL
Defaulters:		
Black	28 (80)	7 (20)
White	6 (85.7)	1 (14.3)
Participants:		
Black	223 (43.8)	286 (56.2)
White	234 (81.8)	52 (18.2)

TABLE 8(iii): CHILDHOOD ENVIRONMENT: PARTICIPANTS AND DEFAULTERS

Adult Socio-economic Status

The majority of non-participants were middle income earners. In the group of management protected and

non-responders, these income earners were mainly whites which was the same as for participants. The majority of the defaulters were black, of which 26 were middle income earners and therefore a great loss to the survey. An attempt was made to offset this loss by the inclusion of the black men from South African Breweries.

GROUP	TOTAL	INCOME (RANDS PER ANNUM) Number (Percent of Group)	
	NO.	<10 000	≥ 10 000
Mx protected	187	176 (94.1)	11 (5.9)
Non-responders	168	119 (70.8)	49 (29.2)
Defaulters	42	10 (23.8)	32 (76.2)
Participants	808	504 (62.4)	304 (37.6)

TABLE 8 (iv): CURRENT INCOME: PARTICIPANTS AND NON-PARTICIPANTS

Smoking Status

The number of smokers amongst non-participants was marginally smaller than that of participants. This difference was, however, not statistically significant. No information was available for the management protected group.

GROUP	NO.	SMOKING STATUS NUMBER (PERCENT OF GROUP)		
		NEVER	PREVIOUS	SMOKERS
Non-responders	168	70 (41.7)	34 (20.2)	64 (38.1)
Defaulters	42	7 (16.7)	21 (50.0)	14 (33.3)
Participants	808	321 (39.7)	145 (18.0)	342 (42.3)

TABLE 8 (v): SMOKING HABITS: PARTICIPANTS AND NON-PARTICIPANTS

8.3 SOCIAL STRATIFICATION SURVEY

Since an objective, validated means of social stratification classification applicable to all individuals in the survey was not available, data obtained from the social stratification sections of the questionnaire of all participants was analysed in order to identify the best social stratification indicators. Social stratification was analysed for two periods: childhood and adulthood. The section on statistical methodology (see Chapter 7) described the technique used to select social stratification indicators and to investigate their value in stratifying the study population.

8.3.1 Childhood Social Stratification Status

The section comprising "childhood status" was completed by 790 (99.25%) of 796 participants whose data was analysed. Six (0.75%) participants did not complete all the components of this section because either the translator was not available, or not proficient in the individual's language. Where a question was not understood, or the answer could not be recalled, or if for any reason the question was not answered, the data were recorded as missing data (md). The univariate analysis of the social stratification survey is presented in Tables 8 (vi) and 8 (viii). Table 8 (vi) summarizes the response to those questions which had been identified prior to analysis as presumptive indicators of childhood social stratification. They are presented in the order in which they were anticipated to be indicative of social status. Each indicator was divided into two categories reflecting either higher or lower social class. The responses are presented for the whole population and then for the two "race" groups.

42.5% of the population were born in a rural area. The vast majority of those born in a rural area (86.6%) were blacks. Blacks were approximately equally split into those born in an urban area (43.8%) and those born in a rural area (56.2%). Of the blacks born in an urban area, 98% were born in the Johannesburg areas of Soweto (83%) and Alexandra Township (15%), the remaining were born in Cape Town and Durban (2%). Those blacks born in the rural areas were mostly from the Nkandla District, Eastern Transvaal (80%) or Western Transvaal (16%), the remainder (4%) being born in the Transkei or Ciskei areas. Of the whites born

in the urban areas, 89% were born in Johannesburg, 9% in Cape Town or Durban and 2% elsewhere. Only 18.2% of whites were born in rural areas, of whom the majority (98%) were born in the Eastern Transvaal.

PRESUMPTIVE INDICATORS	STUDY POPULATION N = 796			BLACKS N = 510			WHITES N = 286		
	N	%	MD	N	%	MD	N	%	MD
1. Place of birth: Urban	457	57.5	1	223	43.8	1	234	81.8	0
Rural	338	42.5		286	56.2		52	18.2	
2. Father's occupation: Non-manual	517	69.1	48	244	52.4	44	273	96.8	4
Manual	231	30.9		222	47.6		9	3.2	
3. No. of siblings: ≤ 3	366	46.2	3	155	30.5	2	211	74.0	1
≥ 4	427	53.8		353	69.5		74	26.0	
4. Sibling death: Yes	512	65.2	11	213	42.3	7	60	21.3	4
No	273	34.8		290	57.7		222	78.7	
5. House type: Brick & mortar	564	71.1	3	279	54.9	2	285	100	1
Natural elements (kraal)	229	28.9		229	45.1		0	0	
6. Household fuel: Electricity	190	23.9	0	8	1.6	0	182	63.6	0
Wood/coal	606	76.1		502	98.4		104	36.4	
7. Highest school education : \geq Std 9 or 10	401	50.7	5	162	32.0	4	239	83.9	1
$<$ Std 9 or 10	390	49.3		344	68.0		46	16.1	

(N = number; % = percentage; MD = missing data)

TABLE 8 (vi): PRESUMPTIVE CHILDHOOD SOCIAL STRATIFICATION INDICATORS (UNIVARIATE ANALYSIS)

Only 3.9% (9) of the group whose fathers occupied manual positions in the workforce when they were children (as defined by Simkins²⁵⁰) were white. Two hundred and forty-four blacks (52.4%) were born into families whose fathers were employed in non-manual occupations, giving in number a group comparable to the whites (273 men). Table 8 (vii) below demonstrates the spread of the two "races" within the occupation

groups. It may be seen that although the number of subjects whose father's occupied non-manual positions were similar, the fathers of black subjects were mostly employed in the middle occupation category (e.g. clerical, sales personnel and teachers), while the fathers of whites were equally spread between this category, as well as the highest category (e.g. professionals, executives).

The number of siblings was greater in the black group, with 353 (69.5%) of this group having 4 or more siblings as compared to only 74 (25%) of whites. A sibling death was also more common in the black group, 213 (43.3%), as compared to 60 (21.3%) in the white group. This must be seen in the context of the greater family sizes and is not intended to represent mortality rates.

All whites lived in homes made of brick and mortar, while 229 blacks (45%) lived in homes composed of natural elements (kraals). The fuel source used for both cooking and heating was also very different. In the homes of 502 (98.4%) of blacks, wood or coal was the fuel source (6 used dung as well), with only 1.6% having access to electricity. Sixty-three percent of whites had electricity as their main fuel source. A further difference in home heating was the absence of a chimney in 267 (53.2%) of homes in which wood/coal was used as the heating and cooking fuel among the blacks. The absence of a chimney was confined to kraals and not a feature of brick and mortar structures.

The population was equally split into those who obtained a standard nine or ten education, 401 (50.7%) and those who did not, 390 (49.3%). Of the latter group, 344 (88.2%) were blacks and only 46 (11.8%) were white. Only 162 (32%) of the blacks completed standards nine or ten, of whom (49) 30% only completed standard nine. 239 (83.9%) of the whites completed standard ten.

GROUP	NO.	NON-MANUAL		MANUAL
		Professional, Executives	Clerical, Teachers, Sales Personnel	
Black	466	40 (8.6)	204 (43.8)	222 (47.6)
White	282	139 (49.3)	134 (47.5)	9 (3.2)

TABLE 8 (vii): FATHER'S OCCUPATION DURING CHILDHOOD

POSSIBLE INDICATORS	STUDY POPULATION			BLACKS			WHITES		
	N	%	MD	N	%	MD	N	%	MD
1. Childhood environment: Urban	469	59.1	3	231	45.5	2	238	83.5	1
Rural	324	40.9		277	54.5		47	16.5	
2. Mother's occupation: Non-manual	193	24.5	8	84	16.7	7	176	61.8	1
Manual	595	75.5		419	83.3		109	38.2	
3. Migrant worker (father): Yes	228	30.9	58	209	45.8	54	19	7.0	4
No	510	69.1		247	54.2		263	93.0	
4. Breast fed: Yes	646	86.9	93	453	93.9	28	193	87.3	65
No	57	13.1		29	6.1		28	12.7	
5. Vaccinated: Yes	712	94.3	41	437	91.0	32	275	98.0	9
No	43	5.7		41	9.0		2	2.0	
6. Total children ≤ 4	367	46.4	5	146	28.9	4	221	77.5	1
≥ 5	424	53.6		360	71.1		64	22.5	
7. Access to medical services: Yes	716	92.7	24	443	90.7	22	273	95.5	2
No	56	7.3		45	9.3		11	3.8	
8. Type of medical service:									
1. Clinic (sisters)	96	13.5	82	93	21.1	68	3	1.1	14
2. Clinic (sisters & doctors)	76	10.7		69	15.6		7	2.67	
3. General hospital	99	13.9		77	17.4		22	8.1	
4. Private practitioner	348	48.7		108	24.41		240	88.2	
5. Traditional healer	94	13.2		94	21.31		0	0	
6. Herbalist/chiropractor	1	0.001		1	0.002		0	0	
9. Home ownership: Family owned	504	63.6	3	319	62.9	3	185	64.7	0
Family rented	289	36.4		188	37.1		101	35.3	
10. Housing density/room: $\leq 1/\text{rm}$	220	28.0	11	38	7.6	10	182	63.9	1
$> 1/\text{rm}$	565	72.0		462	92.4		103	36.1	
11. Cooking fuel: Electricity	166	20.9	2	3	0.6	2	163	57.0	0
Wood/coal	628	79.1		505	99.4		123	43.0	
12. Post-school education: Univ/Tech	216	27.4	9	56	11.1	7	124	43.7	2
None	571	72.6		447	88.9		160	56.3	

(n = number; % = percentage; md = missing data)

**TABLE 8 (viii): POSSIBLE CHILDHOOD SOCIAL STRATIFICATION INDICATORS
(UNIVARIATE ANALYSIS)**

Table 8 (viii) summarises those indicators thought to be possible, but not probable indicators of social stratification. The majority of individuals grew up (i.e. lived up to age of 15 years) in the same environment in which they were born.

ALL SUBJECTS

BORN	GREW UP NUMBER (PERCENT OF GROUP)	
	URBAN	RURAL
Urban	440 (96.5)	16 (3.5)
Rural	29 (8.6)	308 (91.4)

$$x^2 = 619.424$$

$$p = 0.0001$$

This was the same for both "race" groups, as shown below:

BLACK

BORN	GREW UP NUMBER (PERCENT OF GROUP)	
	URBAN	RURAL
Urban	215 (96.4)	8 (3.6)
Rural	16 (5.6)	269 (94.4)

$$x^2 = 415.986$$

$$p = 0.0001$$

WHITE

BORN	GREW UP NUMBER (PERCENT OF GROUP)	
	URBAN	RURAL
Urban	225 (96.6)	8 (3.4)
Rural	13 (25)	39 (75)

$$x^2 = 158.106$$

$$p = 0.0001$$

62.3% of mothers of black families were not income earners, being occupied with rural subsistence farming in rural areas, or housewives in urban areas. 21.3% were employed in manual tasks (e.g. machinists). In total 83.3% of mothers in black families were included in the lower occupation group, while only 16.7% were employed in the higher occupation groups. In sharp contrast, 61.8% of mothers in the white group were employed in tasks included in the upper group, while 38.3% were housewives.

54.2% of fathers in black families had to leave their area of residence (town, village or city) in order to find work. The vast majority of white fathers (93%) did not have to do the same.

Breast feeding was very common in both race groups; but significantly more frequent in the black group, 93.9% and 87.3% in black and white respondents ($\chi^2 = 9.002$ ldf, $p = 0.003$). This question had the highest frequency of missing data, 11.7%, and was the only question to have a greater frequency of missing data in the white group, 22.7%, than the black group, 3.5%. The high frequency of missing data may influence the results of the significant testing which should be interpreted with this fact in mind. Vaccination rates (as determined by recall) were also very common in both groups, but significantly more frequent in the white group, 91% and 98% in black and white respondents ($\chi^2 = 9.002$ ldf $p = 0.003$).

92.7% of the population said they used medical services. There was however a difference in the nature of this health service. 88.2% of the white group, and only 24.4% of the black group, saw a private practitioner as their first contact. The most common health service used by the blacks were those provided by clinics and hospitals (54.1%). 21.2% of the black group saw a traditional healer at the first instance.

Home ownership was equally common in both groups, 62.9% and 64.7% in black and white groups respectively. In the case of blacks, 71.8% of houses owned were kraals and only 28.2% brick and mortar homes. Housing density as defined by number of people per room was greater in the black group, where 92.4% shared a room as compared to the white group, where the majority (63.9%) had their own room.

Post-school education was obtained by only 11.1% of blacks and 43.7% of whites. Only 12% of whites and 1.5% of blacks completed this education in universities.

A. Identification of social stratification indicators

Since criteria for social stratification differ according to the population under investigation and are in any event often highly arbitrary, considerable effort was spent on identifying those criteria most suitable for this study. The overall strategy has been described in detail in Chapter 7, page 133. The results of the analysis of those indicators thought initially to be good indicators of social stratification and their relationship to each other are now presented in the order in which they were expected to be important. The results are summarised in Table 8 (ix).

KAPPA STATISTIC (95% CONFIDENCE INTERVAL)	PLACE OF BIRTH	FATHER'S OCCUP.	NO. OF SIBLINGS	SIBLING DEATH	SCHOOLING	HOUSEHOLD FUEL	HOUSE TYPE
Place of birth							
Father's occupation	0.36 0.29-0.43						
No. of siblings	0.23 0.16-0.30	0.23 0.19-0.29					
Sibling death	0.20 0.13-0.27	0.18 0.13-0.25	0.33 0.27-0.39				
Schooling	0.55 0.49-0.61	0.40 0.33-0.45	0.30 0.23-0.37	0.17 0.10-0.24			
Household fuel	0.17 0.13-0.21	0.13 0.10-0.16	0.21 0.16-0.26	0.10 0.06-0.14	0.25 0.20-0.30		
House type	0.65 0.60-0.70	0.45 0.38-0.52	0.22 0.16-0.28	0.17 0.10-0.24	0.56 0.31-0.61	0.13 0.10-0.16	
"Race"	0.34 0.28-0.40	0.41 0.32-0.44	0.41 0.35-0.47	0.18 0.12-0.24	0.48 0.42-0.54	0.45 0.38-0.52	0.38 0.33-0.43

TABLE 8 (ix): KAPPA INTERRATOR ANALYSIS OF CHILDHOOD SOCIAL STRATIFICATION INDICATORS

1. Place of birth

A strong agreement beyond chance was found between place of birth and

- (i) schooling level achieved, $k = 0.55$ (urban born children being more likely to obtain standard nine or ten than rural children), and
- (ii) type of home, $k = 0.65$ (urban born tending to live in brick and mortar homes, and rural in homes constructed of natural elements).

Moderate agreement, beyond chance, was demonstrated with "race" ($k = 0.34$); whites being more commonly urban born) and father's occupation ($k = 0.36$).

2. Father's occupation

Strong agreement was found between father's occupation (manual vs non manual) and

- (i) schooling level attained, $k = 0.40$ (children of higher occupation group more likely to obtain a standard nine or 10 education);
- (ii) housing type, $k = 0.45$ (brick and mortar being associated with higher work group),
- (iii) race, $k = 0.41$ (fathers of white children being more likely to belong to higher income groups).

Moderate agreement was demonstrated between father's occupation group and place of birth ($k = 0.36$). Poor agreement was found with sibling number ($k = 0.23$) and household fuel ($k = 0.13$).

3. School education achieved

The level of school education achieved was significantly associated with other indicators. A strong relationship was demonstrated between schooling group and

- (i) place of birth ($k = 0.55$) (urban born children were more likely to obtain a standard 9 or 10 education);
- (ii) father's occupation ($k = 0.40$). (Children of the higher paternal occupation group being more likely to obtain more education);
- (iii) housing type, $k = 0.56$, and

(iv) "race" group ($k = 0.48$) (blacks being more likely to complete standard 8 or less).

4. Number of siblings

There was no agreement beyond chance between number of siblings and the other indicators. The only exception was the demonstration of a strong relationship between this indicator and race ($k = 0.41$).

5. Housing Type

Strong relationship was found between housing type and

(i) place of birth (urban living in brick and mortar, rural in houses composed of natural elements), $k = 0.65$;

(ii) father's occupation, $k = 0.45$;

(iii) school level attained, $k = 0.56$, and

Moderate agreement was found between this indicator and race group ($k = 0.38$). Poor agreement was found between housing type and sibling number ($k = 0.22$), sibling deaths ($k = 0.17$) and type of household fuel ($k = 0.13$).

6. Sibling deaths

No relationship greater than can be accounted for by chance could be demonstrated between sibling deaths and any of the other indicators.

7. "Race" group

The exploration of "race" group as social stratum indicator was performed in two stages: firstly to examine how the division of groups by skin colour may itself be an indicator of social stratification and, secondly, to examine the relationship between social strata indicators and race as defined by skin colour.

"Race" was clearly significantly related to all the previously described presumptive social status indicators. Strong agreement beyond chance was demonstrated with

(i) school level attained ($k = 0.48$);

(ii) household fuel ($k = 0.45$);

- (iii) number of siblings ($k = 0.41$);
 (iv) father's occupation ($k = 0.41$).

Moderate agreement was demonstrated with place of birth, $k = 0.36$, and type of housing ($k = 0.38$).

A relationship greater than that due to chance was not demonstrated between "race" and sibling mortality ($k = 0.18$).

In conclusion, the use of kappa interrator analysis allowed the identification of father's occupation, school education, place of birth and "race" as the "best indicators" of childhood social stratification. These indicators were then used in further analyses investigating the inter relationship of different indicators of social stratification. They were also used in the regression and covariance analyses investigating the relationship between lung function and social stratification.

B. Comparison of social stratification groups (childhood indicators)

The results of the second phase of the investigation into social stratification are presented in this section. In this phase the population was stratified into high and low black social stratification groups, and a high white social stratification group, using the "best indicator" father's occupation. The differences, as assessed by χ^2 or Fisher's exact test, between the high black and high white groups and the high black with low black group with respect to the other indicators of social stratification are presented in Table 8 (x - xii) and discussed in the following paragraphs.

STRATIFICATION INDICATOR	GROUP			BETWEEN RACES		WITHIN BLACK	
	*HIGH WHITE	*HIGH BLACK	*LOW BLACK	χ^2 VALUE	P VALUE	χ^2 VALUE	P VALUE
Urban born	81.7%	58.0%	28.8%	34.635	0.001	40.117	0.001
Sibling no. < 4	75.7%	32.5%	26.6%	97.024	0.001	1.957	0.162
Sibling deaths no.	79.2%	62.6%	51.8%	17.252	0.001	5.400	0.020
Schooling \geq Std 9	85.3%	44.2%	19.5%	96.240	0.001	32.328	0.001
Household fuel**	39.2%	1.2%	0.9%	107.899	0.001	*	1.000
House type**	100%	68.3%	38.4%	101.679	0.001	41.630	0.001

* Fisher's exact test

+ On father's occupation

** Household fuel: electricity

** House type: brick and mortar

TABLE 8 (x): COMPARISON OF STRATIFIED POPULATION GROUPS (USING FATHER'S OCCUPATION) WITH RESPECT TO SOCIAL STRATIFICATION INDICATORS

STRATIFICATION INDICATOR	GROUP			BETWEEN RACES		WITHIN BLACK	
	⁺ HIGH WHITE	⁺ HIGH BLACK	⁺ LOW BLACK	χ^2 VALUE	P VALUE	χ^2 VALUE	P VALUE
Urban born	84.1%	85.2%	24.8%	0.87	0.768	162.808	0.001
Sibling no. < 4	97.9%	71.3%	43.1%	59.630	0.001	32.328	0.001
Sibling deaths no.	80.3%	32.3%	29.7%	92.746	0.001	0.363	0.547
Schooling \geq Std 9	81.7%	61.5%	56.1%	20.031	0.001	*	0.250
Household fuel**	44.6%	2.5%	0.3%	82.929	0.001	161.585	0.001
House type ⁺⁺	100%	95.6%	34.8%	*	0.001	*	0.001

* Fisher's exact test

** Household fuel: electricity

⁺ On father's occupation

⁺⁺ House type: brick and mortar

TABLE 8 (xi): COMPARISON OF STRATIFIED POPULATION GROUPS (USING SCHOOL EDUCATION) WITH RESPECT TO SOCIAL STRATIFICATION INDICATORS

When father's occupation is used to stratify the population, the comparison of the "high" groups of both "race" groups reveals differences with respect to place of birth, sibling deaths, number of siblings, school education achieved, household fuel and housing type. Using the same indicator to stratify the "black" population, differences are found with respect to place of birth, sibling deaths, schooling and house type, but not with respect to the number of siblings or household fuel. Thus, a clear difference between white and black is demonstrated, while the black population is demonstrated to be of similar social stratification level for certain indicators.

The use of schooling as the stratification indicator demonstrates differences between white and black "high" group with respect to father's occupation, sibling number, sibling death, household fuel and house type. Within the black population, differences are demonstrated with respect to place of birth, father's occupation, household fuel and house type. No significant differences are found in the black group with respect to number of siblings and sibling deaths.

C. Comparison of place of birth and other adult social stratification indicators

The relationship demonstrated between place of birth and the other presumptive social stratification indicators prompted a closer analysis of the effects of place of birth on social stratification. The results of

urban born whites with urban born blacks, as well as urban born blacks with rural born blacks, are shown in Table 8 (xii).

STRATIFICATION INDICATOR	GROUP			BETWEEN RACES		WITHIN BLACK	
	⁺ HIGH WHITE	⁺ HIGH BLACK	⁺ LOW BLACK	X ² VALUE	P VALUE	X ² VALUE	P VALUE
Urban born	96.5%	68.8%	39.2%	60.693	0.001	40.117	0.001
Sibling no. < 4	76.8%	34.2%	27.4%	83.707	0.001	2.782	0.095
Sibling deaths no.	81.7%	64.6%	52.1%	16.998	0.001	7.802	0.005
Schooling \geq 9	86.3%	61.9%	8.5%	35.514	0.001	162.808	0.001
Household fuel	43.7%	1.8%	0.4%	108.820	0.001	*	0.176*
House type	100%	94.1%	22.5%	14.301	0.001	254.432	0.001

* Fisher's exact test

** Household fuel: electricity

⁺ On father's occupation

⁺⁺ House type: brick and mortar

TABLE 8 (xii): COMPARISON OF STRATIFIED POPULATION GROUPS (USING PLACE OF BIRTH) WITH RESPECT TO SOCIAL STRATIFICATION INDICATORS

In all cases a statistically significant difference between urban born whites and urban born blacks were found. In the comparison of black rural born with black urban born, the differences were also statistically significant except for number of siblings and household fuel.

8.3.2 Adult Social Stratification Status

These were investigated using the same approach outlined for childhood parameters. These indicators and their responses are summarized in Table 8 (xiii).

INDICATORS	STUDY POPULATION			"BLACKS"			"WHITES"		
	N	%	MD	N	%	MD	N	%	MD
PROBABLE - ADULT									
++ Dependents: ≤ 4	454	57.5	6	176	34.9	5	278	97.5	1
≥ 5	336	42.5		329	65.1		7	2.5	
++ R income: ≥ 10,000	381	47.9	0	124	24.3	0	257	89.9	0
< 10,000	415	52.1		386	75.7		29	10.1	
++ Grade: Jun/Snr Admin	463	58.2	0	196	38.4	0	267	93.4	0
Man-labour/Cat	333	41.8		314	61.6		19	6.6	
++ House type: Privately owned	397	49.9	0	164	37.2	0	233	81.5	0
Public Housing	399	50.1		346	67.8		53	18.5	
++ * ADEC: 1	442	55.9	6	169	33.3	2	273	96.8	4
2	348	44.1		339	66.7		9	3.2	
+ Current fuel: Electricity	499	67.4	56	240	50.2	32	259	98.9	24
Wood/coal	241	32.6		238	49.8		3	1.1	
+ Total income: (Additional): 1	149	47.2		24	14.5		125	83.3	
2	122	38.6	480	98	59.0	344	24	16.0	136
3	45	14.2		44	26.5		1	0.7	

n = number; % = percentage of group; md = missing data; ++ = presumptive indicators; + = possible indicators; * see page 134.

TABLE 8 (xiii): ADULT (CURRENT) SOCIAL STRATIFICATION INDICATORS

The number of dependents supported by the individual surveyed is very different for the two race groups. 97,5% of whites have 4 or less dependants, whereas only 34,9% of the "black" men have 4 or less

dependants. 93% of the population earning R10,000/year or less are "blacks", with only 7% of "whites" being included in this income group. "White" men occupy the more senior positions, with 93.4% of the white study population occupying administrative or other senior posts. 61.6% of blacks and only 6.6% of whites are employed in the lower occupation group, including manual labour such as cleaning, catering (not chefs) and security guards. The discrepancy between grade and income between the two race groups is also demonstrated by 38.4% of blacks being employed in the higher work group, but only 63.3% of these earn > R10,000/year. Home ownership is also different between the two groups with only 37.2% of black men owning their own home, compared with 81.5% of white men. The composite index ADEC includes virtually all the white men in the upper group, 96.8%, but only 33.3% of black men.

The two possible indicators, current home fuel and total additional income, are also included in this table. Although improved since childhood, only 50.2% of black men have electricity as a fuel source, with 49.8% still relying on wood or coal, while 96.8% of white men have electricity.

A. Identification of adult social stratification indicators

The results of the analysis comparing the social indicators with each other are summarized in Table 8 (xiv).

1. Current Income

Strong agreement beyond chance is demonstrated between current income and position within the workforce ($k = 0.73$), as might be expected. Strong relationships are also demonstrated with

- (i) number of dependants ($k = 0.49$),
- (ii) home ownership ($k = 0.54$), and
- (iii) household fuel source ($k=0.48$); and
- (iv) "race" group ($k = 10.61$).

INDICATOR KAPPA STATISTIC (95% confidence interval)	Current Income	Current Occupation	Dependants	House type	Fuel	Race
Current income						
Current occupation	0.73 0.68-0.78					
No. of dependants	0.49 0.43-0.55	0.47 0.41-0.52				
House type	0.54 0.48-0.60	0.53 0.47-0.59	0.46 0.40-0.52			
Current fuel	0.48 0.42-0.54	0.50 0.44-0.56	0.44 0.38-0.50	0.48 0.42-0.54		
Race	0.61 0.55-0.67	0.48 0.43-0.53	0.56 0.51-0.61	0.45 0.39-0.51	0.40 0.35-0.45	
ADEC	0.76 0.71-0.81	0.80 0.76-0.84	0.64 0.59-0.69	0.71 0.66-0.76	0.68 0.63-0.73	0.56 0.51-0.61

(* P = < 0.01 in all cases on Chi squared testing)

**TABLE 8 (xiv): RESULTS OF ADULTHOOD (CURRENT) SOCIAL STRATIFICATION
INDICATOR***

2. Current occupation

There is strong agreement between the position an individual occupies within the workforce, as divided into manual (labourers, catering staff and security guards) and non-manual (clerical, administrative, computer operating, junior management) and all the other social indicators. This position in the workforce is closely related, as expected, to (i) income ($k = 0.73$) group, (ii) number of dependants ($k = 0.47$), (iii) housing ownership ($k = 0.53$), (iv) home fuel source ($k = 0.50$) and (v) race group ($k = 0.53$). In all cases, those included in the higher occupation category (non-manual) are associated with features categorized in the high group of the other indicators. In the "race" category the association indicates a strong relationship between the high occupation category and being white.

3. Number of Dependants (≤ 4 dependants = high; > 4 dependants = low)

When the number of dependants is used as an indicator of social class a strong agreement ($p = 0.01$) is demonstrated between this indicator and other markers of social stratification. In each case those individuals with four or fewer dependants were more likely to belong to the higher groups in each of the other categories. A strong relationship beyond chance is demonstrated between number of dependants and

- (i) income group, $k = 0.49$,
- (ii) occupational grade, $k = 0.47$,
- (iii) house ownership, $k = 0.46$,
- (iv) current fuel use, $k = 0.44$ and
- (v) race group, $k = 0.56$,

blacks being associated with a larger number of dependants.

4. House Ownership (high = owned; low = rented)

Home ownership is also a good indicator of social stratification. Agreement beyond chance is demonstrated with

- (i) income group ($k = 0.54$),
- (ii) position in the workforce ($k = 0.53$),
- (iii) number of dependants ($k = 0.46$),
- (iv) home fuel source ($k = 0.48$) and
- (v) "race" ($k = 0.45$).

5. Fuel Source

For all indicators of social stratification, a strong relationship is demonstrated between fuel source and the other indicators, with electricity being associated with the higher category in each case.

6. "Race"

Strong agreement is found between all social indicators and race group as defined by skin colour.

In summary it may be seen that the "best indicators" of current (adulthood) social stratification include current income, occupation, home ownership, fuel source and "race" and the composite current indicator (ADEC) was chosen as the "best" indicator to stratify the population in further investigations relating social stratification to race and place of birth, as well as lung function.

B. Comparison of stratified groups (adult indicators)

STRATIFICATION INDICATOR	+HIGH WHITE	GROUP		BETWEEN RACES		WITHIN BLACK	
		+HIGH BLACK	+LOW BLACK	X ² VALUE	P VALUE	X ² VALUE	P VALUE
Grade Jnr/Snr Admin	97.7%	93.6%	20.7%	*	0.076	210.344	0.001
Dependants ≤4	97.7%	52.4%	29.1%	120.561	0.001	22.341	0.001
House ownership	85.2%	63.7%	22.0%	22.701	0.001	74.765	0.001
ADEC	99.6%	88.6%	15.6%	*	0.001	223.969	0.001

* Fisher's exact test

+ on current income

TABLE 8 (xv) (a): COMPARISON OF STRATIFIED POPULATION GROUPS (USING CURRENT INCOME) WITH RESPECT TO ADULT SOCIAL STRATIFICATION INDICATORS

STRATIFICATION INDICATOR	+HIGH WHITE	GROUP		BETWEEN RACES		WITHIN BLACK	
		+HIGH BLACK	+LOW BLACK	X ² VALUE	P VALUE	X ² VALUE	P VALUE
Income > R10000	89.7%	41.3%	11.2%	119.755	0.001	61.472	0.001
Grade Jnr/Sn Admin	93.2%	65.0%	17.5%	55.341	0.001	119.823	0.001
Dependants ≤ 4	97.9%	53.4%	20.3%	123.997	0.001	59.862	0.001
House ownership	81.6%	56.5%	12.9%	33.912	0.001	109.246	0.001
ADEC (high)	96.1%	60.4%	12.3%	85.948	0.001	129.815	0.001

+ on place of birth

TABLE 8 (xv) (b): COMPARISON OF STRATIFIED POPULATION GROUPS (USING PLACE OF BIRTH) WITH RESPECT TO ADULT SOCIAL STRATIFICATION INDICATORS

In this section the results of investigating the relationship between social stratification groups (as defined by the "best" adult indicators) and the other social stratification indicators is presented (see Table 8 (xv)).

HIGH WHITE GROUP/HIGH BLACK GROUP

Differences are found for dependants, type of house and adult education. The difference in grade is not statistically significant.

HIGH BLACK/LOW BLACK

Significant differences are found between blacks belonging to the high income group and those included in the lower group.

The analysis demonstrates that all adult indicators are able to identify stratification differences within the black population.

C. Comparison of place of birth and adult social stratum indicators

The significant differences between urban born whites and blacks are summarized in Table 8 (xv) (B). Differences are found for income, grade, dependants, house type and ADEC.

URBAN BLACKS/RURAL BLACKS

Urban born blacks differ significantly from rural born blacks for income, grade, dependants, house type and ADEC.

Urban born blacks are shown to be significantly better off than rural born blacks with respect to all adult stratification indicators.

8.3.3 Comparison of Childhood and Adulthood Social Stratification

INDICATOR Kappa Statistic (95% confidence interval)	Father's occup.	School educ	Sib. die	Sib. no.	House type	Fuel	Born
INCOME	0.39 0.33-0.45	0.57 0.51-0.63	0.15 0.09-0.21	0.29 0.22-0.36	0.48 0.43-0.53	0.24 0.19-0.29	0.42 0.36-0.48
CURRENT OCCUPATION	0.40 0.33-0.47	0.52 0.46-0.58	0.18 0.11-0.25	0.25 0.19-0.31	0.59 0.53-0.65	0.16 0.12-0.20	0.50 0.44-0.56
DEPENDANTS	0.34 0.27-0.41	0.54 0.48-0.54	0.17 0.10-0.24	0.28 0.22-0.34	0.52 0.46-0.58	0.20 0.16-0.24	0.44 0.38-0.50
HOUSE OWNERSHIP	0.38 0.32-0.44	0.48 0.42-0.54	0.17 0.11-0.23	0.25 0.18-0.39	0.48 0.42-0.54	0.15 0.10-0.20	0.45 0.39-0.51
FUEL	0.43 0.36-0.50	0.42 0.36-0.48	0.21 0.14-0.28	0.25 0.19-0.31	0.47 0.40-0.54	0.13 0.10-0.16	0.38 0.31-0.45
ADEC	0.45 0.39-0.51	0.59 0.53-0.65	0.19 0.12-0.26	0.28 0.22-0.34	0.61 0.56-0.66	0.20 0.16-0.24	0.53 0.47-0.59

TABLE 8 (xvi): KAPPA ANALYSIS: CHILDHOOD vs ADULTHOOD SOCIAL STRATIFICATION INDICATORS

School education achieved, type of housing and father's occupation are the childhood indicators of social stratification most significant to adult indicators. The strongest relationships were demonstrated for the indicators, school education and house type, but a strong relationship was also demonstrated for the indicator father's occupation. The adult indicator with the strongest relationship with the presumptive childhood indicators is the composite indicator ADEC. Current position in the workforce and income are the adult social stratification indicators with the next strongest relationship to childhood indicators. Current home ownership and fuel source also have stronger relationships with these indicators. Number of siblings, sibling deaths and childhood fuel source are poorly related to adult social stratification.

The use of the childhood indicator, father's occupation, to stratify the population demonstrates the following: those born with a white skin to father's in the high category are strongly related to the adult indicators, since whites were significantly associated with the higher categories of these indicators. Equally, within the black group, those born into families living in urban areas demonstrate a strong relationship with the Higher categories of each of the adult social stratification indicators. The best indicators of childhood stratification are Pajob and school education. School education is, however, likely to be influenced by several factors not directly to socio-economic status (e.g. availability of schools in rural areas) and for this reason it was decided that father's occupation was the preferred social stratification indicator.

The results of the social stratification investigation also demonstrated (1) that within the study population the best indicator of social stratification was "skin colour"; (2) that the black group is inferior to the white group with respect to every indicator of social stratification that we examined; (3) that within the black population a very slight social stratification gradation is demonstrated. This gradation suggests the beginnings of upward social mobility within the black community.

8.4 SPIROMETRIC LUNG FUNCTION SURVEY (FVC AND FEV1)

8.4.1 Description of Tests Performed

Lung function tests were attempted on the total survey population, except for 2 (0.25%) individuals. The 2 who did not undergo testing did not do so for the following reasons:

- (i) fear of aggravating previous inguinal hernia repair (black male),
- (ii) refusal to participate because of anticipated difficulty with performing tests (white male).

767 (96.4%) attempted flow volume loops (Autolink) and 729 (91.6%) spirometry (Vitalograph). 702 (88.2%) attempted both Autolink and Vitalograph testing (see Fig 8 (ii)). 722 (90.7%) flow volume loops and 693 (87.1%) spirometry met American Thoracic Society and Inter Mountain Thoracic Society standards for acceptability and reproducibility. 646 (81.16%) had both flow volume loops and spirometry meeting these standards (See Table 8 (xvii)).

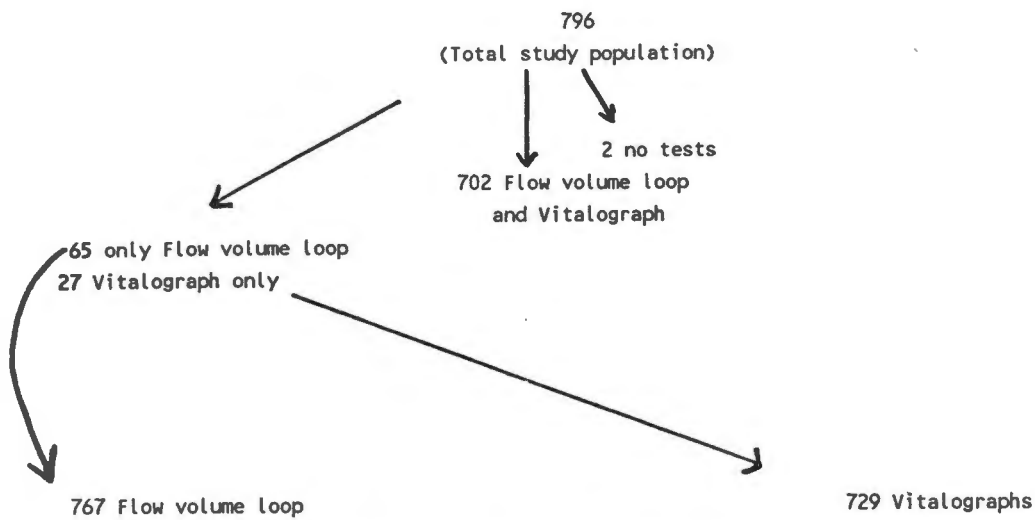


FIG 8 (ii): FLOW DIAGRAM SPIROMETRY ACHIEVED

FLOW VOLUME LOOPS (n)	VITALOGRAPHS (n)			TOTALS
	Accepted	Rejected	Missing	
Accepted	646	14	62	722
Rejected	27	15	3	45
Missing	20	7	2	29
Totals	693	36	67	796

TABLE 8 (xvii): DESCRIPTION OF TESTING ACHIEVED - CROSS TABULATION OF FLOW VOLUME LOOP AND VITALOGRAPH

Of the "white" men 283 (99.0%) attempted flow volume loops, 258 (90.2%) attempted spirometry and 255 (89.5%) attempted both. In the black group 484 (94.9%) attempted flow volume loops, 471 (92.4%) attempted spirometry and 446 (87.5%) attempted both. The rejection rate (those not meeting ATS/ITS standards) for flow volume loops tended to be greater for blacks (7.02% rejected functions) than for whites (3.8%),

although this fell just short of statistical significance (χ^2 3.184 (1df), $p = 0.074$). In the case of spirometers the rejection rate for blacks (7.01%) was significantly greater than for whites (1.17%) (χ^2 6.286 = 1 df $p = 0.0001$). In the black group the rejection rate for both tests was similar (7.01 and 7.02%) while for whites the rejection rate for flow volume loops (3.8%) was worse than for spirometers (1.17%) (χ^2 4.458 = 1 df $p = 0.05$). In the group who performed both tests (90.1% of blacks and 95.3% of whites) the rejection rate (of one or other test or both tests) was greater for blacks (9.57%) than for whites (4.69%) (χ^2 4.287 = 1 df $p = 0.01$). The greatest rejection rate for functions was within the "black" rural born group who had 10.86% of their flow volume loops and 8.99% of spirometers rejected. This was significantly more than the number of flow volume loops rejected in the white urban group ($\chi^2 = 9.856$, 1 df; $p = 0.002$) and the urban born black group ($\chi^2 = 13.328$, 1 df; $p = 0.0041$). Their Vitalograph rejection rate was also significantly worse than the urban born white group ($\chi^2 = 14.3666$, 1 df; $p = 0.001$) and worse than the urban born black group ($\chi^2 = 3.666$, 1 df; $p = 0.056$). The rejection rates for the study population divided into social strata (using father's occupation as the indicator) are outlined in Table 8 (xviii)

SOCIAL* STRATIFICATION GROUP	HIGH WHITE (n = 273) n (Percent of Group)			HIGH BLACK (n = 244) n (Percent of Group)			LOW BLACK (n = 222) n (Percent of Group)		
	A/L	V/G	BOTH	A/L	V/G	BOTH	A/L	V/G	BOTH
Test attempted	270 (98.9)	248 (90.8)	246 (90.1)	238 (97.5)	231 (94.7)	25 (92.3)	203 (91.4)	201 (90.5)	183
Test not done	3 (1.1)	25 (9.2)	27 (9.9)	6 (2.5)	13 (5.3)	19 (7.7)	19 (8.6)	21 (9.5)	39
Quality									
Accepted	259 (95.9)	245 (98.8)	234 (95.1)	226 (95)	218 (94.4)	212 (94.2)	186 (91.6)	184 (91.5)	159
Rejected	11 (4.1)	3 (1.2)	12 (4.9)	12 (5.0)	13 (5.6)	13 (5.8)	17 (8.4)	17 (8.5)	24

(*Stratified by father's occupation) A/L = Autolink V/G = Vitalograph

**TABLE 8 (xviii): COMPARISON TESTING PERFORMED IN SOCIAL STRATIFICATION GROUPS
(INDICATOR = FATHERS'S OCCUPATION)**

There was no significant difference in the rejection rates between the "black" "low" group and the "black" "high" group for either spirometers ($\chi^2 = 1.980$, 1df; $p = 0.159$), or flow volume loops ($\chi^2 = 1.332$, 1 df; $p =$

= 0.248). The rejection rate for flow volume loops was significantly worse for the "black" "low" group ($\chi^2 = 3.848$, 1 df; $p = 0.050$) but not for the "black" "high" group ($\chi^2 = 0.274$, 1 df; $p = 0.601$) compared to the "white" high group. The rejection rate for Vitalographs was, however, significantly worse in both black groups, $\chi^2 = 7.230$; $p = 0.007$ (high) and $\chi^2 = 13.704$, 1 df; $p = 0.0061$ (low) compared to the "white" "high" group.

8.4.2 Anthropometric population data

The anthropometric data for the whole study population are summarized in Tables 8 (xix-xxi) and Figures 8 (iii-vi) below. The mean age of the study population was 40.1 years (standard deviation 10.53) with a range of 20-72 years. The median age was 39 years. The frequency distribution of ages is summarized in Tables 8 (xix - xx) below. For 33 individuals (21 black, 2 white) accurate ages could not be obtained since a discrepancy of 5 or more years between the ages recorded at next birthday or calculated from date of birth or by the personnel department of the Bank was found. The data of these individuals were not included in the analysis of age or the analysis of lung function.

AGE GROUP (yrs)	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
< 25	39	5.0	39	5.0
25-34	213	27.6	252	32.6
35-44	278	36.0	530	68.6
45-54	162	21.0	692	89.5
55-64	64	8.3	756	97.8
65+	17	2.2	773	100.0

TABLE 8 (xix): FREQUENCY DISTRIBUTION OF AGE - STUDY POPULATION

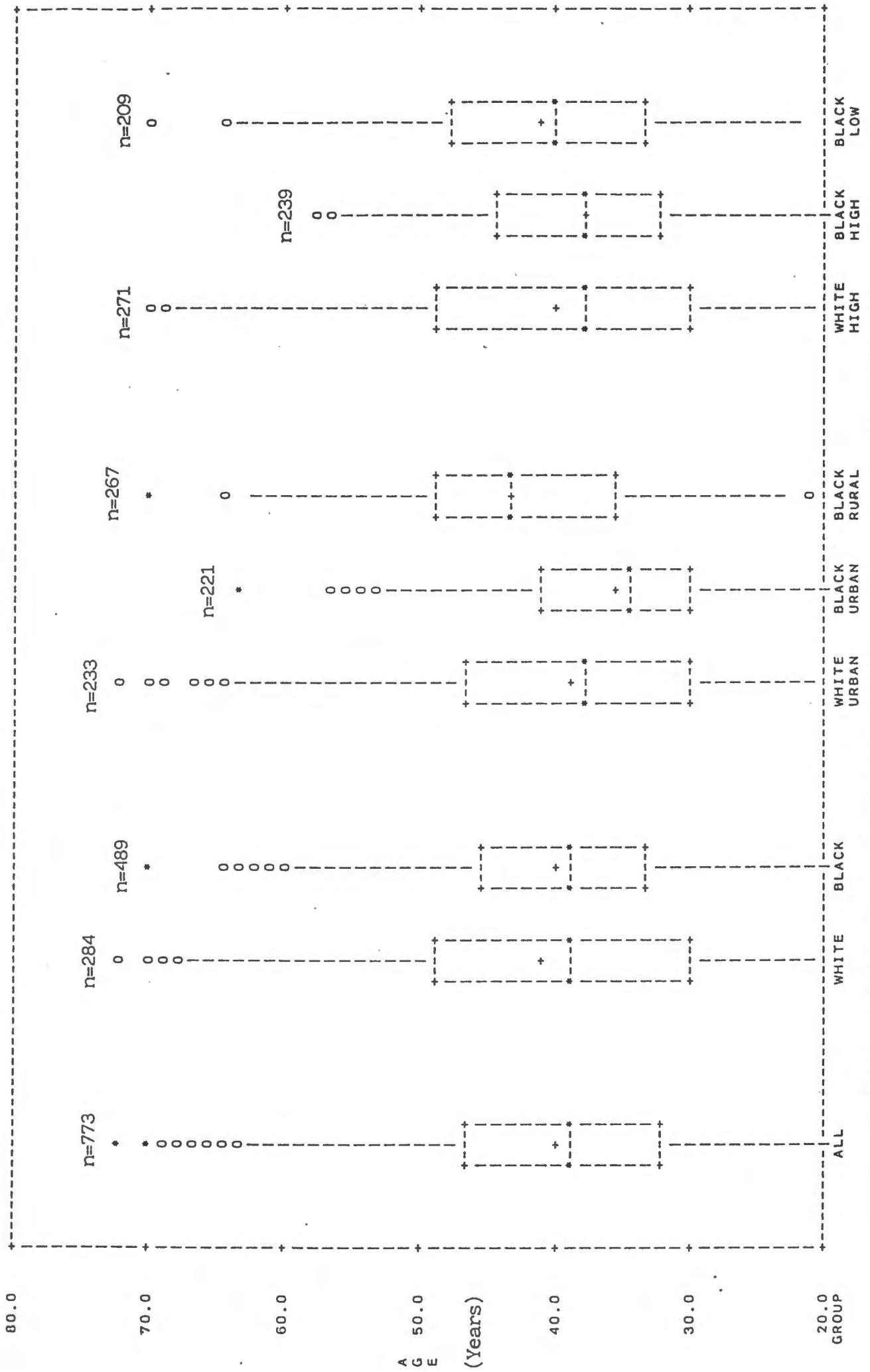


Fig 8 (III) BOX PLOTS - AGES IN SOCIAL STRATIFICATION GROUPS (WHOLE POPULATION)

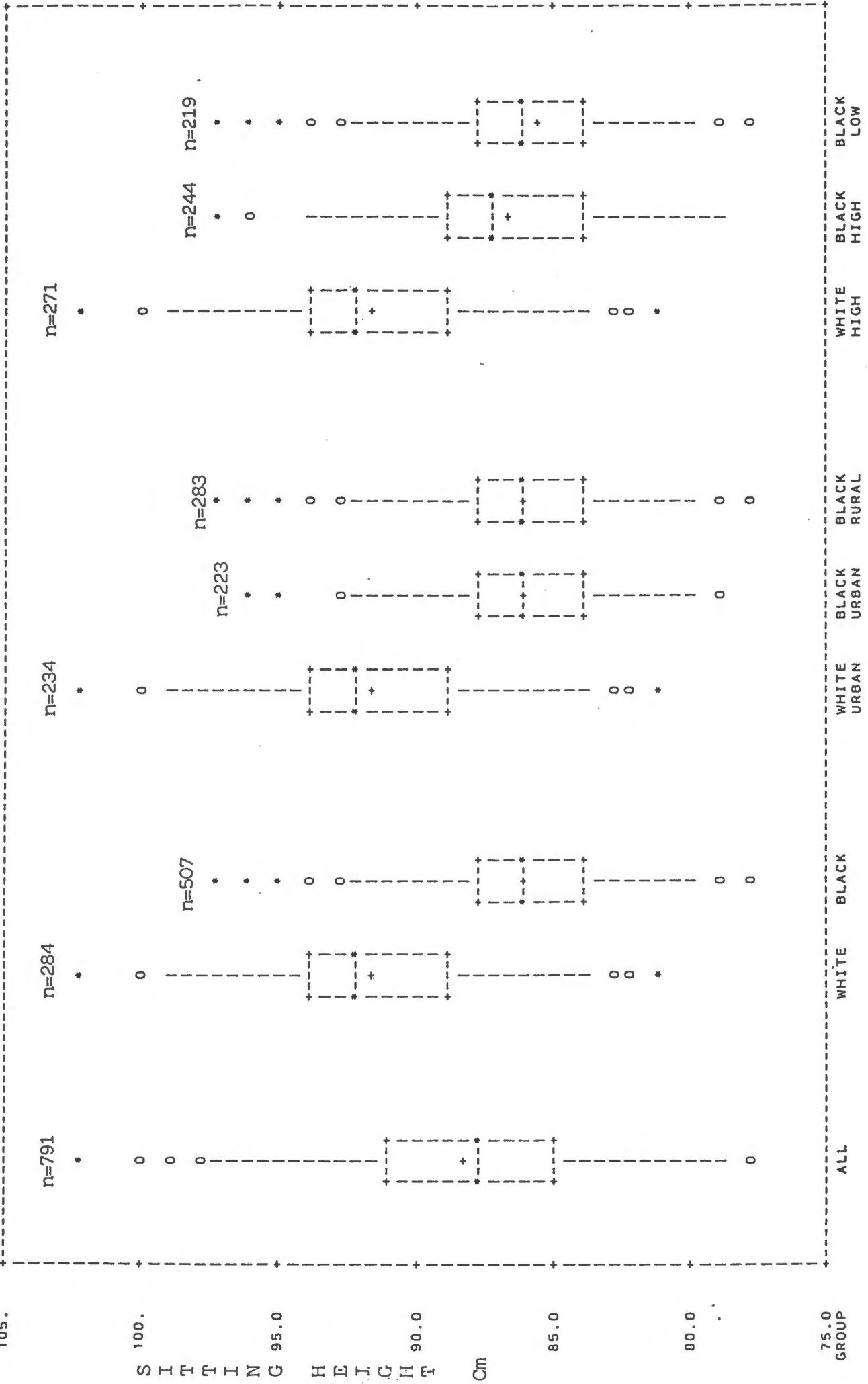


Fig 8 (IV): BOX PLOTS - SITTING HEIGHT (WHOLE POPULATION)

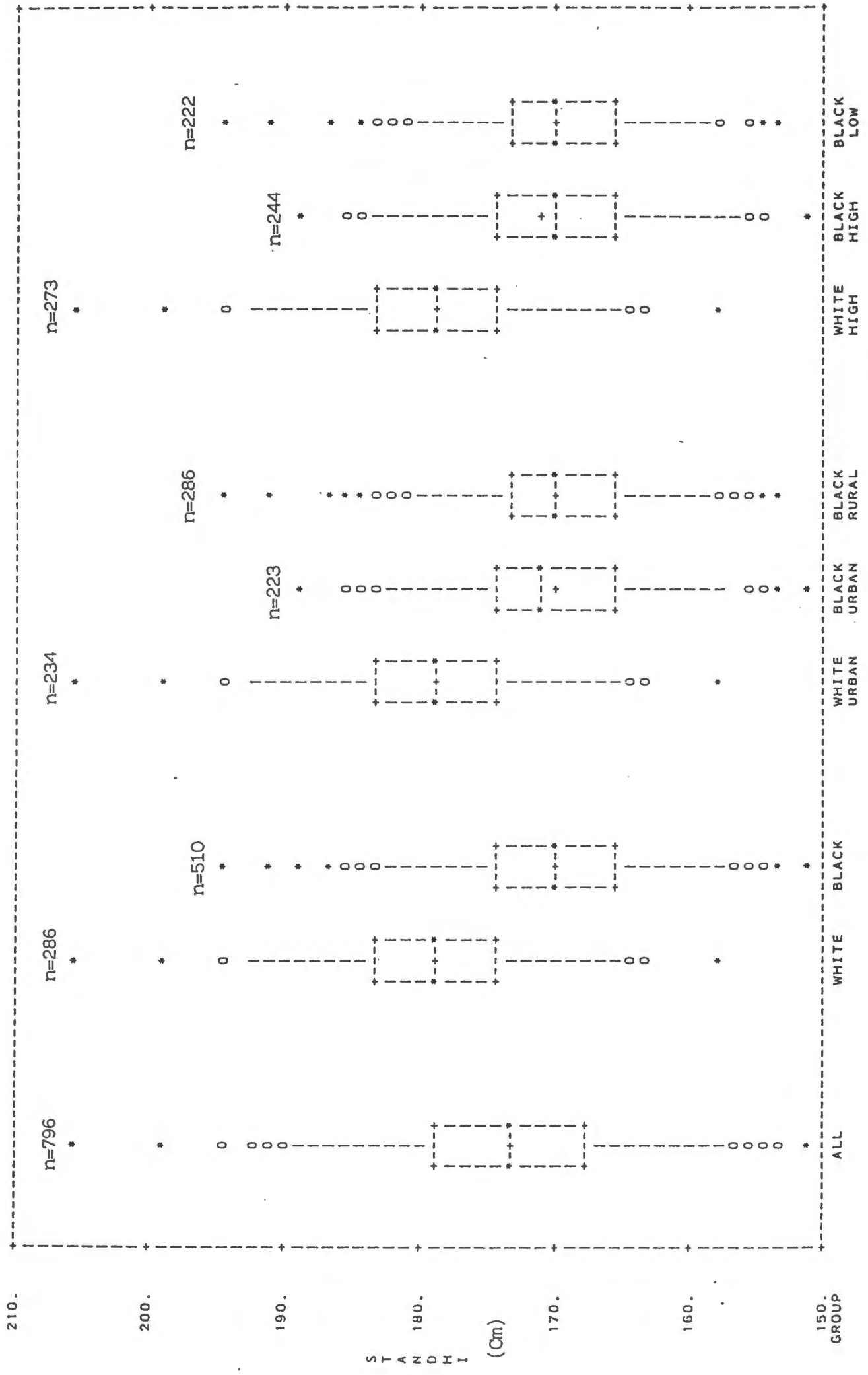


Fig 8 (V): BOX PLOTS -- STANDING HEIGHT (WHOLE POPULATION)

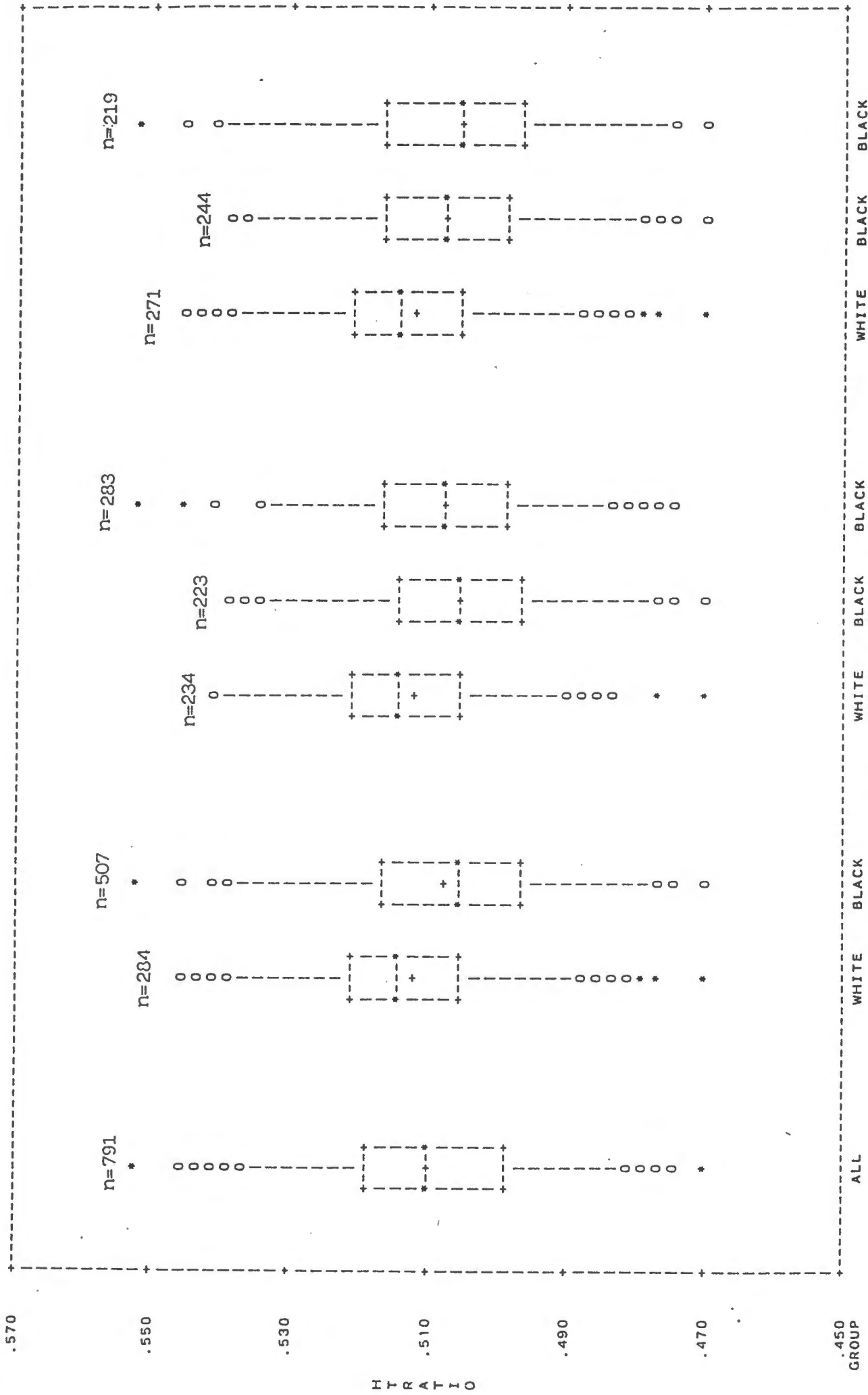


Fig 8 (VI): BOX PLOTS - SITTING HEIGHT/STANDING HEIGHT RATIO (WHOLE POPULATION)

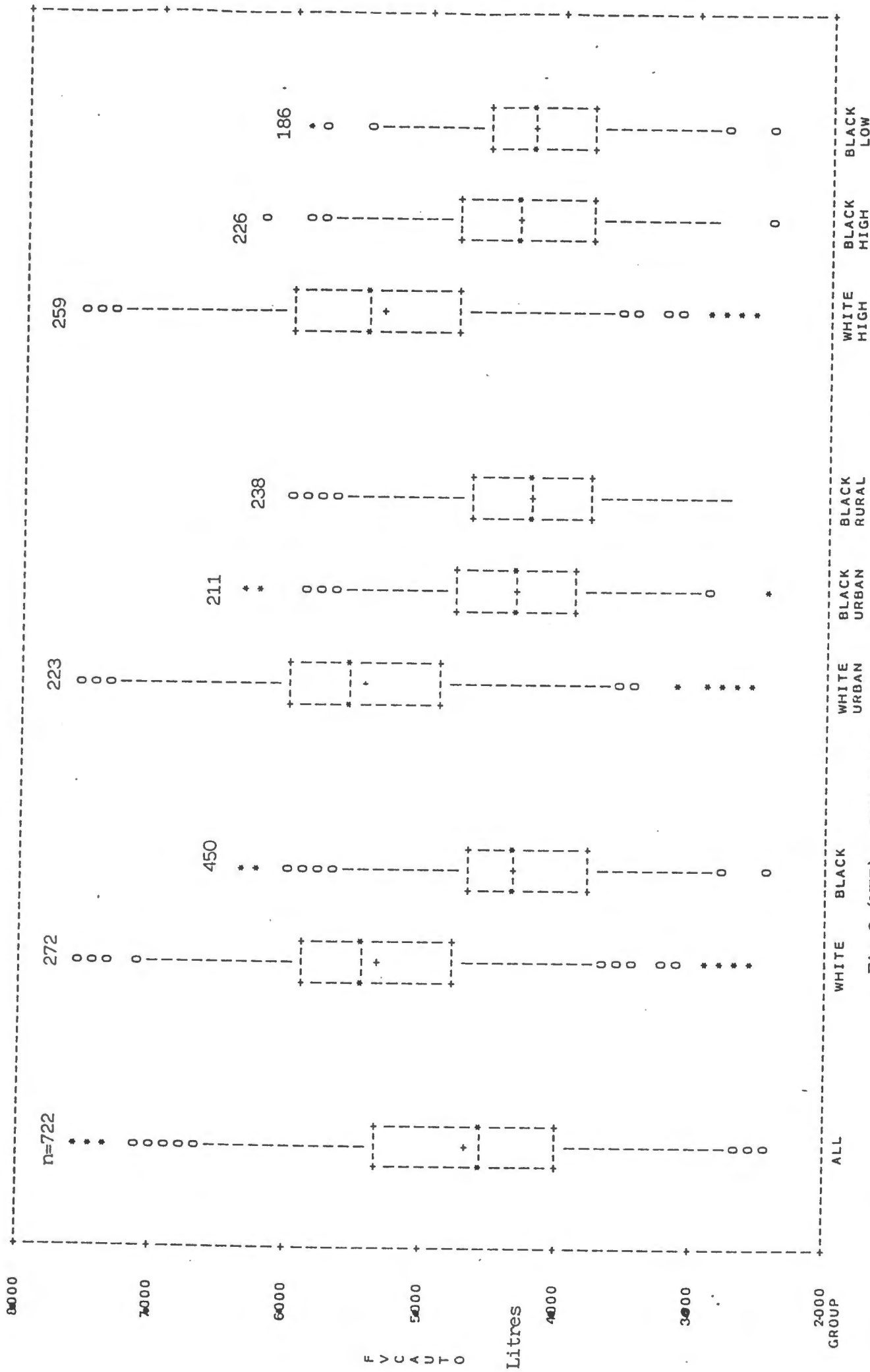


Fig 8 (VII): BOX PLOTS - FVC (L/L) (WHOLE POPULATION)

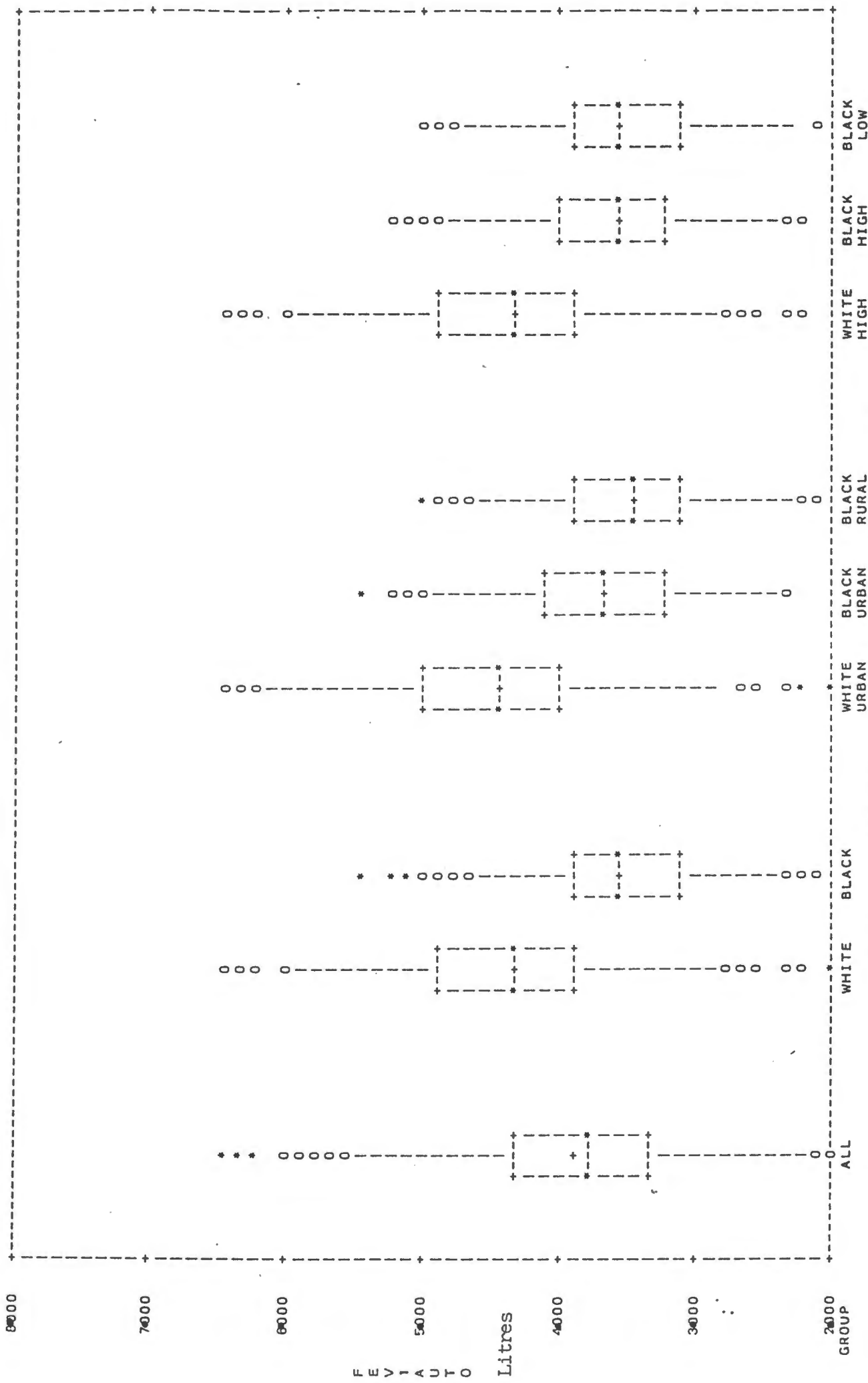


Fig 8 (VIII): BOX PLOTS - FEV1 (A/L) (WHOLE POPULATION)

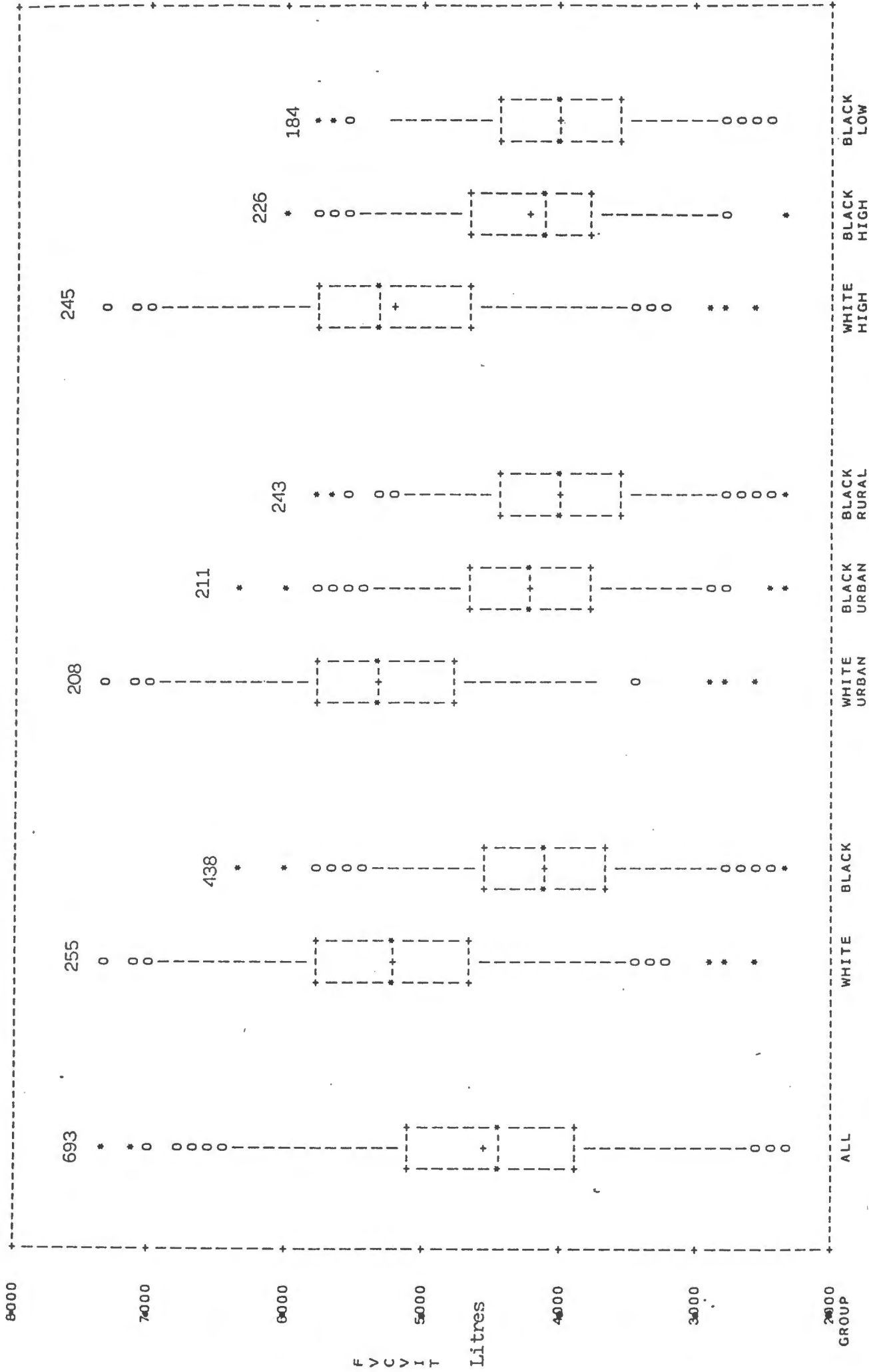


Fig 8 (IX) - FVC (VITALOGRAPH) (WHOLE POPULATION)

AGE GROUP (yrs)	SOCIAL STRATIFICATION GROUP (Percentage of social stratification group)				
	BLACK n = 489	WHITE n = 284	*HIGH WHITE n = 271	*HIGH BLACK n = 239	*LOW BLACK n = 209
< 25	15 3.1	24 8.5	23 8.5	12 5.0	3 1.4
25-34	138 28.2	75 26.4	74 27.3	73 30.5	55 26.3
35-44	191 39.1	87 30.6	83 30.6	96 40.2	80 38.3
45-54	107 21.9	55 19.4	51 18.8	49 20.5	47 22.5
55-64	36 7.4	28 9.8	26 9.6	9 3.8	22 10.5
65+	2 0.4	15 5.3	14 5.2	0 0.00	2 0.1

* stratification indicator = father's occupation

**TABLE 8 (xx): FREQUENCY DISTRIBUTION OF AGES IN SOCIAL STRATIFICATION GROUPS
DEFINED BY RACE AND FATHER'S OCCUPATION**

MEASUREMENT	TOTAL STUDY POPULATION	SOCIAL STRATIFICATION GROUPS NUMBER IN GROUP							
		"RACE"		ENVIRONMENT (URBAN/RURAL)			SOCIO-ECONOMIC FATHER'S OCCUPATION		
		Black	White	White Urban	Black Urban	Black Rural	White High	Black High	Black Low
	All 796	Black 510	White 286	White Urban 234	Black Urban 223	Black Rural 286	White High 271	Black High 244	Black Low 222
Age (yrs)	M 40.1 SD 10.6 R 20-72 n 773	39.8 9.4 20-70 489	40.6 12.4 21-72 284	39.3 11.8 21-72 233	36.0 8.1 20-63 221	42.9 9.2 21-70 267	40.4 12.3 21-7 271	38.1 8.7 20-58 239	41.3 9.8 22-7 209
Sit Ht (cm)	M 88.2 SD 4.3 R 78-102 n 791	86.2 3.3 78-97 507	91.7 3.6 81-102 284	91.7 3.6 81-102 234	86.1 3.4 79-96 223	86.2 3.2 78-97 283	91.7 3.7 81-102 271	86.6 3.2 79-97 244	85.8 3.2 78-97 219
Stand Ht (cm)	M 173.2 SD 7.8 R 151-195 n 796	170.1 6.5 151-195 510	178.8 6.8 158-206 286	178.7 6.7 158-206 234	170.4 6.5 151-189 223	169.9 6.5 153-195 286	178.9 6.8 158-206 273	170.6 6.6 151-189 244	169.6 6.4 153-195 222
Weight (kg)	M 75.5 SD 13.2 R 45-123 n 796	77.4 12.5 45-123 510	80.9 12.5 48-132 286	80.9 12.8 48-132 234	71.2 12.5 45-122 223	73.5 12.5 45-123 286	80.9 12.6 48-116 273	73.6 13.1 45-123 244	71.7 12.3 45-122 222
Hi ratio	M 0.51 SD 0.01 R 0.46-0.55 n 791	0.51 0.01 0.46-0.55 507	0.51 0.01 0.47-0.55 284	0.51 0.01 0.47-0.54 234	0.51 0.01 0.47-0.54 223	0.51 0.01 0.47-0.55 283	0.51 0.01 0.47-0.55 271	0.51 0.01 0.47-0.55 244	0.51 0.01 0.47-0.55 219

M = mean; SD = standard deviation; R = range; n = number measurements performed; Sit Ht = sitting height; Stand Ht = standing height; Hi ratio = sitting/standing height ratio

TABLE 8 (xxi): ANTHROPOMETRIC RESULTS (WHOLE STUDY POPULATION)

The mean age for the two "race" groups was similar; 39.8 (blacks) and 40.6 (whites) (t test; $p = 0.91$). The average ages of the urban born (mean 38.1, standard deviation 8.69) and "high" (36.04 ± 8.103) (defined by father's occupation) black groups were the lowest, while the mean ages of the "black rural" ($42.87 \text{ yrs} \pm 9.23$) and black low group ($41.3 \text{ yrs} \pm 9.8$) are the highest. The sitting height of the "white" group (mean 91.7 cm, standard deviation 3.620) is significantly higher than the "black" group (86.207 ± 3.258) (t test; $p = 0.001$). There is no difference in height within the black group when divided either by place of birth or by social class (as defined by father's occupation). The same is true for standing height which is higher for the white group ($178.8 \text{ cm} \pm 6.8$) than the black group ($169.7 \text{ cm} \pm 6.0 \text{ cm}$) (t test; $p = 0.001$). The mean sitting height/standing height ratio for the study population is 0.51 ± 0.1 . There is no difference in the mean sitting/standing ratio for the black (0.507 ± 0.013) or white (0.513 ± 0.013) groups (t test; $p = 0.746$). There is no difference in this ratio when the groups are divided by either place of birth or father's occupation.

8.4.3 Spirometric Lung Function Measurements (Whole Population)

The results for the mechanical lung function tests (FVC; FEV₁ and FVC/FEV₁ ratio) are presented separately for the 2 different apparatuses used. The raw data is presented in Figures 8 (vii) - 8 (x). These results must be interpreted cautiously in the light of the different anthropometric measurements, smoking habits and respiratory health status. The anthropometric and lung function measurements obtained for the healthy group are addressed later in this chapter in the sections dealing with the determinants of normal lung function.

8.5 SMOKING SURVEY

Smoking histories were obtained from 793 (99.6%) of the participating subjects and are shown in Table 8 (xxii). Lifelong never-smokers constituted 39.7% of the study population. There was no significant difference between the number of never-smokers in the two race groups. Previous smokers were more common in the white group, 23.4%, than the black group, 14.8%. Previous smokers constituted 17.8% of the study population. "White" smokers were more likely to be heavy smokers (> 10 cigarettes/day) (28.7%) whereas "black" smokers were more likely to be light smokers (< 10 cigarettes/day) (25.8%). Blacks who

PERCENTAGE BLOCK CHART

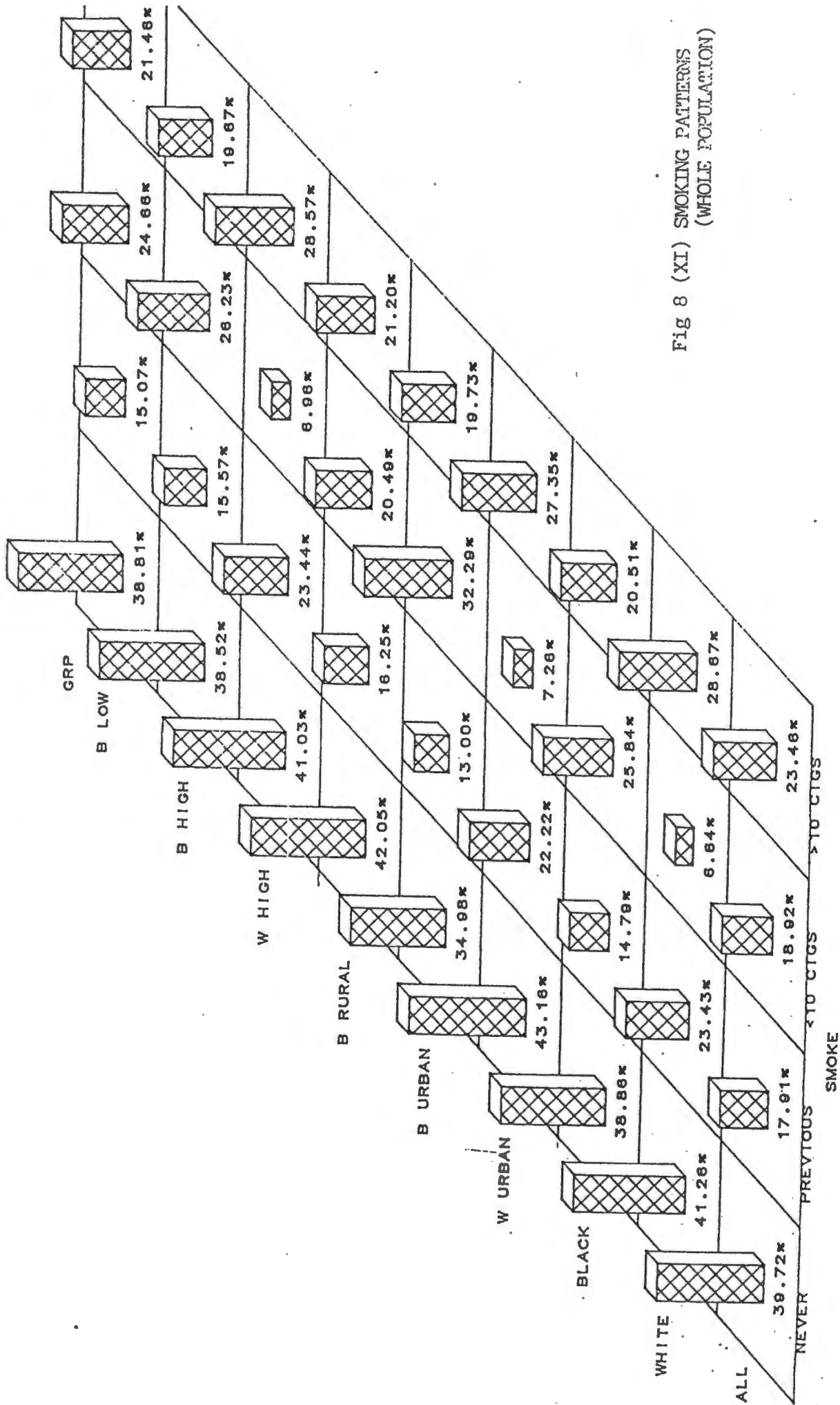


Fig 8 (XI) SMOKING PATTERNS (WHOLE POPULATION)

belonged to high stratification groups, whether defined by place of birth or father's occupation, are currently more likely to be smokers than any of the other groups (see Fig 8 (xi)).

SMOKING PATTERN	GROUP																	
	*n = 796 All		*n = 510 Black		n = 286 White		n = 234 Urban White		n = 223 Urban Black		n = 283 Rural Black		+n = 273 High White		+n = 244 High Black		*+n=219 Low Black	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Never smokers	315	(39.7)	197	(38.9)	118	(41.3)	101	(43.2)	78	(35)	119	(42.0)	112	(41.0)	94	(38.5)	85	(38.8)
Previous smokers	142	(17.9)	75	(14.8)	67	(23.4)	52	(22.2)	29	(13)	46	(16.3)	64	(23.4)	38	(15.6)	33	(15.1)
Light smokers (< 10/day)	150	(18.9)	131	(25.8)	19	(6.6)	17	(7.3)	72	(32.3)	58	(20.5)	19	(7.0)	64	(26.2)	54	(24.7)
Heavy smokers (> 10/day)	186	(23.4)	104	(20.5)	82	(28.7)	64	(27.4)	44	(19.7)	60	(21.2)	78	(28.6)	48	(19.7)	47	(21.5)

* missing data = 3; + = stratification indicator father's occupation

TABLE 8 (xxii): SMOKING PATTERNS

A log linear model was fitted to investigate the relationship between smoking patterns and age and social stratification indicators race and place of birth. A significant interaction was found between smoking, ethnic group and age; as well as an interaction between ethnic group and place of birth; and between place of birth and age (likelihood ratio χ^2 5.79; 1 df 9; $p = 0.7605$).

Carboxy haemoglobin (COHb) measurements were made on 65 of the randomly selected sub-group on whom repeat measurements were made. The COHb measurements are summarised in Table 8 (xxiii) below. The median carboxyhaemoglobin of smokers is significantly higher than previous smokers (median test; $p = 0.001$) and current smokers (median test; $p = 0.001$). The median values are reported because they are not affected by extreme values. In the case of never smokers, all but two individuals had measured

CoHb levels within one standard deviation of the mean. The CoHb levels of these two individuals was 3.6 and 4.5. Similarly, all but one of the previous smokers had levels within one standard deviation of the mean. One individual had a measured CoHb of 6.2. These outliers probably reflect the difficulty in accepting validity of smoking histories without objective measurements.

CARBOXYHAEMOGLOBIN	SMOKING HABITS		
	Never n = 31	Previous n = 9	Current n = 25
Mean (SD)	1.6 (0.8)	2.1 (1.6)	4.4 (2.9)
Median	1.4	1.7	3.8
Range	0.2 - 4.5	0.9 - 6.2	0.7-11.7

TABLE 8 (xxiii): COHb ESTIMATIONS IN DIFFERENT SMOKING GROUPS

8.6 RESULTS OF THE RESPIRATORY HEALTH QUESTIONNAIRE

The results of the respiratory health questionnaire are summarised in Table 8 (xxiv). Included in this table is the information relating to past and present occupation in adverse respiratory environments. The most frequent symptoms are those of cough (7.6%), sputum production (8.3%) and combinations of these two symptoms (6.9%). Comparison of the incidence of these symptoms between "blacks" and "whites" demonstrates no statistically significant difference in the incidence of cough (χ^2 ; $p = 0.219$), sputum production (χ^2 ; $p = 0.132$). The incidence of frequent cough with phlegm production is significantly lower in blacks than whites (χ^2 ; $p = 0.044$). No significant differences are demonstrated for any other adverse respiratory features between the two race groups.

RESPIRATORY SYMPTOMS AND DISEASE Number (%) Data set	GROUP NUMBER (PERCENTAGE OF GROUP)								
	ALL n = 796	BLACK n = 510	WHITE n = 286	WHITE URBAN n = 234	BLACK URBAN n = 224	BLACK RURAL n = 286	WHITE HIGH n = 273	BLACK HIGH n = 244	BLACK LOW n = 396
Cough n	62 (7.9) 787	35 (7.0) 501	27 (9.4) 286	22 (9.4) 234	21 (9.4) 223	14 (5.1) 277	26 (9.5) 273	19 (7.8) 244	12 (5.6) 216
Phlegm n	67 (8.6) 787	37 (7.4) 498	30 (10.6) 286	27 (11.6) 234	23 (10.3) 223	14 (5.1) 274	29 (10.7) 273	16 (6.7) 241	18 (8.4) 215
Cough/Phlegm n	56 (7.0) 784	27 (9.4) 498	28 (9.4) 286	23 (9.8) 234	16 (7.2) 223	12 (4.2) 275	26 (9.5) 273	15 (6.2) 241	9 (4.2) 215
Wheeze n	26 (3.3) 787	17 (3.3) 501	9 (3.2) 286	8 (3.4) 234	13 (5.8) 223	4 (1.4) 277	8 (2.9) 273	9 (3.7) 242	7 (3.2) 216
Breathlessness n	2 (0.3) 787	1 (0.2) 501	1 (0.4) 286	1 (0.4) 234	0 (0) 223	1 (0.4) 277	1 (0.4) 273	0 242	1 (0.5) 216
Chest injury n	26 (3.3) 784	15 (3.0) 498	11 (3.9) 286	10 (4.3) 234	6 (2.7) 223	9 (3.3) 274	11 (4.0) 273	6 (2.5) 241	9 (4.2) 214
Chest surgery n	6 (0.8) 784	2 (0.4) 498	4 (1.4) 286	3 (1.3) 234	2 (0.9) 223	0 (0) 274	4 (1.5) 273	1 (0.4) 241	0 (0) 214
Pulmonary TB n	19 (2.4) 784	19 (3.8) 498	0 (0) 286	0 (0) 234	12 (5.4) 223	7 (2.6) 274	0 273	12 (5.0) 240	5 (2.3) 215
Heart disease n	14 (1.8) 786	6 (1.2) 500	8 (2.8) 286	7 (3.0) 234	3 (1.4) 223	3 (1.1) 276	7 (2.6) 273	3 (1.2) 241	5 (2.3) 216

TABLE 8 (xxiv) RESPIRATORY HEALTH FEATURES- RESPIRATORY SYMPTOMS AND DISEASE

The respiratory symptoms, including cough (χ^2 ; $p = 0.01$) and phlegm production, and wheeze are significantly lower (χ^2 ; $p = 0.01$ in each case) in rural born "black", compared with both urban born whites and blacks. No significant difference is demonstrated between these latter two groups. Similar results are obtained when the incidence of symptoms is compared in the low stratification black group and the higher black and white groups. Pulmonary tuberculosis was reported by 19 blacks and no whites (χ^2 ; $p = 0.001$). The prevalence of this condition was greatest in "blacks" in the higher stratification groups, e.g. urban born versus rural born (Fisher's exact; $p = 0.017$) and father's occupation non-manual vs manual (χ^2 ; $p = 0.001$). The results of exposure to an adverse respiratory environment are summarised in Table 8 (xxvii). Of particular interest is the similarity of previous dust exposure in the various sub-groups.

OCCUPATIONAL RISK	GROUP NUMBER (PERCENTAGE OF GROUP) (No. in group)								
	ALL n = 796	BLACK n = 510	WHITE n = 286	WHITE URBAN n = 234	BLACK URBAN n = 223	BLACK RURAL n = 286	WHITE HIGH n = 273	BLACK HIGH n = 244	BLACK LOW 221
Asbestos	11 (1.4) 794	8 (1.6) 508	3 (1.1) 286	3 (1.3) 234	3 (1.4) 223	5 (1.8) 284	2 (0.7) 273	4 (1.6) 244	7 (1.8) 221
Mine	18 (2.2) 794	8 (1.6) 508	10 (3.5) 286	8 (3.4) 234	4 (1.8) 223	4 (1.4) 284	10 (3.7) 273	5 (2.1) 244	2 (0.9) 221
Foundry	11 (1.4) 794	5 (1.0) 508	6 (2.1) 286	4 (1.7) 234	2 (0.9) 223	3 (1.1) 284	6 (2.2) 273	5 (2.1) 244	0 (0.0) 221
Quarry	8 (1.0) 794	4 (0.8) 508	4 (1.4) 286	4 (1.7) 234	0 (0) 223	4 (1.4) 284	4 (1.4) 273	1 (0.4) 244	3 (1.4) 221
Other dust exposure	32 (3.9) 794	23 (4.5) 508	9 (3.2) 286	7 (3.0) 234	9 (4.0) 223	14 (4.9) 284	8 (2.9) 273	9 (3.7) 244	9 (4.1) 661
Grain	22 (2.7) 794	17 (3.3) 508	5 (1.5) 286	4 (1.7) 234	5 (2.2) 223	12 (4.2) 284	4 (1.5) 273	9 (3.7) 244	7 (3.2) 221
Dusty job	29 (3.6) 794	18 (3.5) 508	11 (3.9) 286	7 (3.0) 234	6 (2.7) 223	12 (4.2) 284	11 (4.0) 273	8 (3.3) 244	6 (5.6) 221

TABLE 8 (xxv): RESPIRATORY HEALTH FEATURES- OCCUPATIONAL RISK**8.7 QUALITY CONTROL****8.7.1 Comparison of repeat interview with survey interview**

For 66 individuals a repeat interview was done following their main survey interview.

On the identification data no differences between the 2 interviews were found with respect to age or date of birth. 2 individuals had differing answers for any of the other identification questions.

6 of the 66 cases had discrepancies on a given question in the childhood data section. The questions with the largest number of differing answers related to the number of siblings and the number of children sharing home.

In the occupational section of the questionnaire there were no differences with regard to asbestos/mine/foundry/quarry/grain employment were noted. However, 5 cases differed regarding work in other dusty places, stating in the repeat interview that they did do dusty jobs. 3 cases differed on the description of dusty job. 2 cases differed on current job description.

In the symptom section of the questionnaire 2 cases gave differing answers for any given symptom. For the questions on length of condition, for which 5 cases differed.

On questions dealing with diseases, 1 case gave a different answer, except for the question about current cold, for which 5 cases stated in the repeat interview that they had colds.

The following differences were found in the smoking questionnaire:

2 cases who in the survey interview reported never having smoked, reported smoking more than 10 cigarettes per day. 1 case first reported smoking more than 10 per day but in repeat survey reported

less than 10. One case, reported both times as smoking more than 10 cigarettes, differed on the number. One case differed on question regarding anyone smoking other leaves in childhood home.

The only discrepancy in the adult socio-economic section was one case for which combined monthly income was not noted in survey interview, but in repeat interview.

8.7.2 Comparison of tape recording with original data

For 67 individuals the tape recording of the interview was compared with the information as coded and entered onto the computer.

No differences were found regarding age or date of birth. The only difference in the identification data was one case for which language was annotated as missing, but was specified on tape. In the childhood data 2 cases differed on father's occupation, 1 on vaccination. 8 cases differed on number of siblings and 4 on number of children in childhood home. For one case there was a discrepancy in number of people in childhood home.

In the occupational section there were no discrepancies regarding asbestos/mine/foundry/quarry/grain employment. However, 11 cases stated in interview that they had some dusty employment, whereas it was noted on the questionnaire that they had not. 5 cases differed on the description of the dusty job. For 1 case information on current job was missing on the data sheet, although stated in interview.

In the symptom section of the questionnaire no more than one case had a discrepancy, except for questions on breathlessness, where 2 cases differed.

On the section dealing with diseases, 3 cases stated in recording that they had cold currently, but was noted on questionnaire as not having cold. The only other discrepancies were 2 cases, one of which differed on age at which chronic bronchitis started, the other age at which the subject first had TB.

There was only one discrepancy in the smoking questionnaire where it was unclear from the tape recording whether the subject smoked more or less than 10 cigarettes, but was noted on questionnaire as smoking more than 10 cigarettes.

The only discrepancy in adult socio-economic section was one case which differed on number of dependants.

8.7.3 Quality Control of Lung Function Survey

A randomly selected group of 54 subjects had repeat measurements of FEV₁ and FVC. 46 had Vitalograph and 38 Autolink measurements on both occasions. The mean FVC (Vitalograph) at the first sitting was 4.69L and on repeat testing 4.62L. The corresponding mean FEV₁ (Vitalograph) measurements were 3.81L and 3.73L. For the group who had Autolink measurements on 2 occasions the mean FVC was 4.54L on the first occasion and 4.67 on the second occasion. The corresponding FEV₁ measurements were 3.98L and 3.91L respectively. The mean difference between the first and second sittings were 0.07L (FVC Vitalograph); 0.14L (FEV₁ Vitalograph); 0.07 (FVC Autolink) and 0.08 (FEV₁ Autolink). These differences were considered to be well within the range of accepted biologic variation.

8.8 CHEST RADIOLOGY SURVEY

Of the 796 men who participated in the survey, 783 had posterior/anterior and lateral chest radiographs done either on the same day, or within a week of attendance at the survey except for 5 who had had radiographs performed within the previous year. The remainder (18) refused to have radiographs but participated in the rest of the survey. The five who had their radiographs performed previously (0.62%) produced the radiographs, together with a radiologist's report. These radiographic examinations had been taken as part of either insurance or executive health evaluation (see Table 8 xxvi).

GROUP	GROUP SIZE	CXR REVIEWED n (% Group)	CXR DONE SURVEY n (% Group)	OTHER X-RAY n (% Group)	NO CXR n (% Group)
Survey population	n = 796	783 (98.4)	778 (97.7)	5 (0.6)	13 (1.6)
Black	n = 510	500 (98.0)	500 (98.0)	0	10 (2)
White	n = 286	283 (97.2)	278 (97.2)	5 (1.8)	3 (1)

TABLE 8 (xxvi): RADIOLOGY SURVEY

The results of the radiological survey are summarised in Table 8 (xxvii) below.

Normal radiographs (i.e. those considered to be free of past or present pathology) were found in 728 subjects (93.0% of those who had X-ray) of which 604 (83%) were classified as absolutely clear; 90 (12.4%) were classified clinically clear but technically imperfect and 34 (4.7%) clear except for calcific spiculation.

When the population is stratified by the social stratification indicator "race", no difference is demonstrated for the technical acceptability rate of radiographs. Stratification into high and lower "father's" income groups within the race groups similarly shows no difference in the overall acceptance rates. A significantly greater number of radiographs which were classified as technically imperfect, but clear, (i.e. code 2/1), was found in the "low" black group (χ^2 ; $p = 0.01$) compared with the higher black group.

Abnormal radiographs (see criteria, Chapter 7, page 126) were found in 55 (7%) of the survey population. The most common abnormality found was hyperinflation (31 radiographs; 56% of abnormal radiographs). The next most common radiographic defect was evidence for local volume loss in 34% of abnormal radiographs. Active local disease was present in 4 (7.2%) and diffuse interstitial disease in 1 radiograph (1.8%).

Comparison of abnormalities detected in radiographs for "black" and "white" subjects demonstrates a significantly greater number of abnormal radiographs in the former group (χ^2 ; = 0.01). Hyperinflated lung fields are the commonest abnormality in "blacks" (63% of abnormal radiographs), local volume loss is more common in the white group (χ^2 ; p = 0.01). When the population is stratified by the indicator father's occupation, the greatest frequency of abnormal radiographs is found in the "black low" group (χ^2 ; p = 0.001) compared to other groups.

Radiographs were used as the criteria for exclusion in the normality screen in only 16 individuals who did not have other reasons for exclusion.

RADIOGRAPH REPORT	GROUP NUMBER (PERCENTAGE OF GROUP)					
	TOTAL SURVEY POPULATION n = 796	BLACK n = 510	WHITE n = 286	HIGH WHITE * n = 273	HIGH BLACK * n = 244	LOW BLACK * n = 222
Clear	604 (77.1)	381 (76.2)	223 (78.8)	214 (79.3)	192 (8.0)	158 (72.8)
Technically imperfect	90 (11.5)	61 (12.2)	29 (10.2)	27 (10)	25 (10.4)	30 (13.8)
Hyperinflated (< 1 cm)	24 (3.1)	17 (3.4)	7 (2.5)	5 (1.9)	6 (2.5)	11 (5.1)
Hyperinflated (> 2 cm)	7 (0.9)	6 (1.2)	1 (0.4)	1 (0.3)	3 (1.3)	3 (1.4)
Local volume loss	19 (2.4)	9 (1.8)	10 (3.5)	10 (3.7)	1 (0.4)	6 (2.8)
Cardiac failure	0 (0)	0	0	0	0	0
Interstitial disease	1 (0.1)	1 (0.2)	0	0	0	1 (0.5)
Local disease	4 (0.5)	3 (0.6)	1 (0.4)	1 (0.4)	3 (1.3)	0
Calcific	34 (4.3)	22 (4.4)	12 (4.2)	12 (4.4)	10 (4.2)	8 (3.7)
Total reviewed	783	500	283	270	240	217
Missing data	13	10	3	3	4	5

(* Stratified by father's occupation)

TABLE 8 (xxvii): RESULTS OF RADIOGRAPH SURVEY

8.9 DETERMINANTS OF LUNG FUNCTION (SPIROMETRY)

8.9.1 Characteristics of Healthy Study Population

The determinants of lung function were analysed using the data obtained from the 208 "healthy" individuals (criteria described in methods chapter 7, page 128), 128 of whom were "black" and 80 "white". 195 (38.2%) blacks and 94 (32.9%) whites were excluded on the basis of their smoking histories only. Other than this criteria, the most frequent reason for exclusion (7.5% of blacks and 10.5% of whites) was the combination of smoking and a respiratory symptom. The radiograph survey resulted in 9 blacks (1.8%) and 7 whites (2.4%) being excluded on the basis of the abnormal radiograph alone. The results of the normality screen (see Methods section) are presented in Table 8 (xxviii) below.

Race	EXCLUSION CRITERIA					Frequency	% of group
	Occupation Risk	Cardio-respiratory illness/symptom/history	Chest injury or surgery	Smoking history	Abnormal radiograph		
BLACK n = 510	0	0	0	0	0	128+	25.1
	0	0	0	0	1	9	1.8
	0	0	0	1	0	195	38.2
	0	0	0	1	1	18	3.5
	0	0	1	0	0	12	2.4
	0	0	1	0	1	3	0.6
	0	0	1	1	0	12	2.4
	0	0	1	1	1	4	0.8
	0	1	0	0	0	15	2.9
	0	1	0	1	0	38	7.5
	0	1	0	1	1	3	0.6
	0	1	1	0	0	7	1.4
	0	1	1	1	0	7	1.4
	0	1	1	1	1	1	0.2
	1	0	0	0	0	15	2.9
	1	0	0	0	1	14	0.8
	1	0	0	1	0	19	3.7
	1	0	0	1	1	1	0.2
	1	0	1	0	0	1	0.2
	1	0	1	1	0	2	0.4
	1	0	1	1	1	1	0.2
	1	1	0	0	0	2	0.4
	1	1	0	1	0	6	1.2
	1	1	0	1	1	2	0.4
	1	1	1	0	0	1	0.2
	1	1	1	1	0	4	0.8

0 = criterion not present
1 = exclusion criterion

+ = healthy black group
++ = healthy white group

TABLE 8 (xxviii): RESULTS OF NORMALITY SCREEN

Race	EXCLUSION CRITERIA					Frequency	% of group
	Occupation Risk	Cardio-respiratory illness/symptom/history	Chest injury or surgery	Smoking history	Abnormal radiograph		
WHITE n = 286	0	0	0	0	0	80++	28.0
	0	0	0	0	1	7	2.4
	0	0	0	1	0	94	32.9
	0	0	0	1	1	5	1.7
	0	0	1	0	0	5	1.7
	0	0	1	1	0	6	2.1
	0	0	1	1	1	1	0.3
	0	1	0	0	0	16	5.6
	0	1	0	1	0	30	10.5
	0	1	0	1	1	5	1.7
	0	1	1	0	0	1	0.3
	0	1	1	1	0	5	1.8
	0	1	1	1	1	2	0.7
	1	0	0	0	0	7	2.5
	1	0	0	0	1	13	4.6
	1	0	0	1	1	1	0.3
	1	0	1	0	0	1	0.3
1	0	1	1	1	0	2	0.7
1	1	0	0	0	0	1	0.3
1	1	0	0	1	0	3	1.0
1	1	1	0	1	1	1	0.3

0 = criterion not present

+ = healthy black group

1 = exclusion criterion

++ = healthy white group

TABLE 8 (xxviii) (continued): RESULTS OF NORMALITY SCREEN**8.9.2 Anthropometric and Spirometric Measurements - Healthy Study Population**

The anthropometric measurements, age distribution and raw spirometric functions for this healthy group are presented in Tables 8 (xxix-xxx) and Figures 8 (xii-xix).

The age distribution of the "healthy" population was similar to the total population with a mean age of 39.6 yrs \pm 10.8. The "healthy" white sub-population was younger than the total white population while the healthy black rural and black lower social stratification group (defined by father's occupation) were older than the equivalent groups in the total study population. There was however no significant difference within this healthy sub-population between these different groups. The various other anthropometric measurements in the "healthy" group were not significantly different to the total study population, nor was there any difference within the various sub-group comparisons between these two population (total and healthy) groups.

HEALTHY GROUP

MEASUREMENT	All n = 208	Black n = 128	White n = 80	White Urban n = 68	Black Urban n = 53	Black Rural n = 75	White High n = 77	Black High n = 59	Black Low n = 60
Age (yrs)	M 39.6 SD 10.8 R 20-70 n 203	41.1 10.2 20-70 123	37.3 11.3 22-68 80	36.7 10.6 22-65 68	36.6 8.5 20-57 53	44.6 10.1 24-70 70	37.2 11.3 22-68 77	38.3 8.9 20-58 58	43.3 10.9 22-70 57
Sit Ht (cm)	M 88.4 SD 4.3 R 79-100 n 206	86.1 3.1 79-93 127	91.6 3.6 85-100 79	92.3 3.5 85-1 68	86.0 3.2 80-92 53	86.3 2.9 79-93 74	92.0 3.5 85-100 76	86.9 3.0 80-92 59	85.5 3.1 79-93 59
Stand Ht (cm)	M 173.2 SD 7.7 R 155-206 n 208	169.7 6.0 155-191 128	178.8 6.8 163-206 80	179.1 6.8 163-206 68	169.4 5.6 155-182 53	169.9 6.3 158-191 75	178.9 6.7 163-206 77	170.7 5.5 611-183 59	168.8 6.5 155-191 60
Weight (kg)	M 76.4 SD 12.0 R 45-126 n 208	73.7 120.2 45-107 128	80.2 13.2 53-126 80	81.3 13.7 53-120 68	71.8 12.5 45-100 53	75.4 11.9 49-107 74	80.2 13.4 53-126 77	75.3 11.6 45-100 59	73.3 12.9 49-100 60
Hi ratio	M 0.51 SD 0.01 R 0.46-0.4 n 206	0.50 0.01 0.46-0.54 127	0.51 0.01 0.48-0.54 79	0.51 0.01 0.49-0.54 68	0.51 0.01 0.47-0.54 53	0.51 0.01 0.49-0.54 74	0.51 0.01 0.48-0.54 76	0.50 0.01 0.48-0.54 59	0.51 0.01 0.48-0.54 59

M = mean; SD = standard deviation; R = range; Sit Ht = sitting height; Stand Ht = standing height; Hi ratio = sitting/standing height ratio
FVC = forced vital capacity; FEV₁ = forced expiratory volume in 1 sec; A/L = Autolink; V/G = Vitalograp

TABLE 8 (xxix): ANTHROPOMETRIC MEASUREMENTS - HEALTHY GROUP

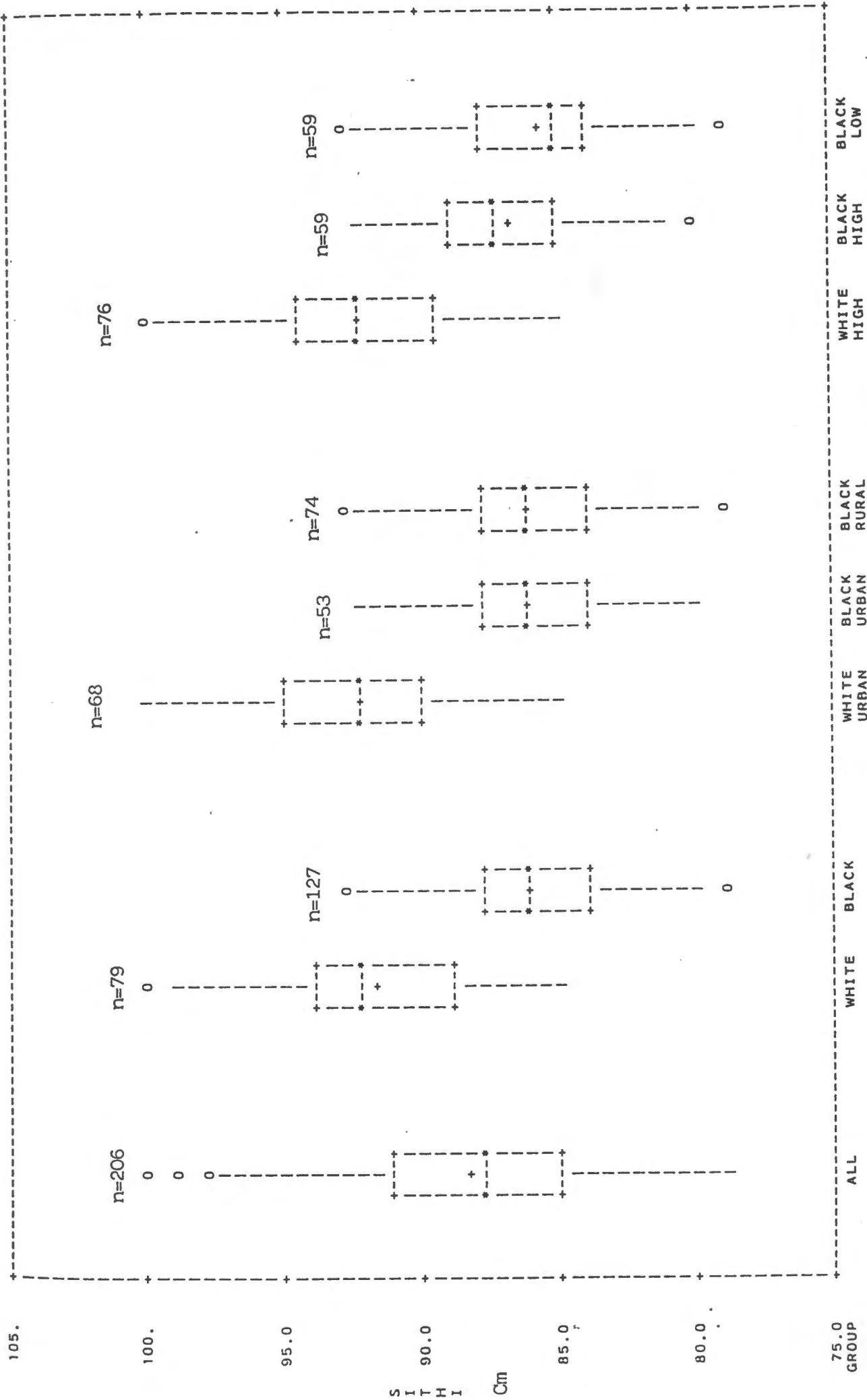


Fig 8 (XIII) BOX PLOTS - SITTING HEIGHTS (HEALTHY GROUP)

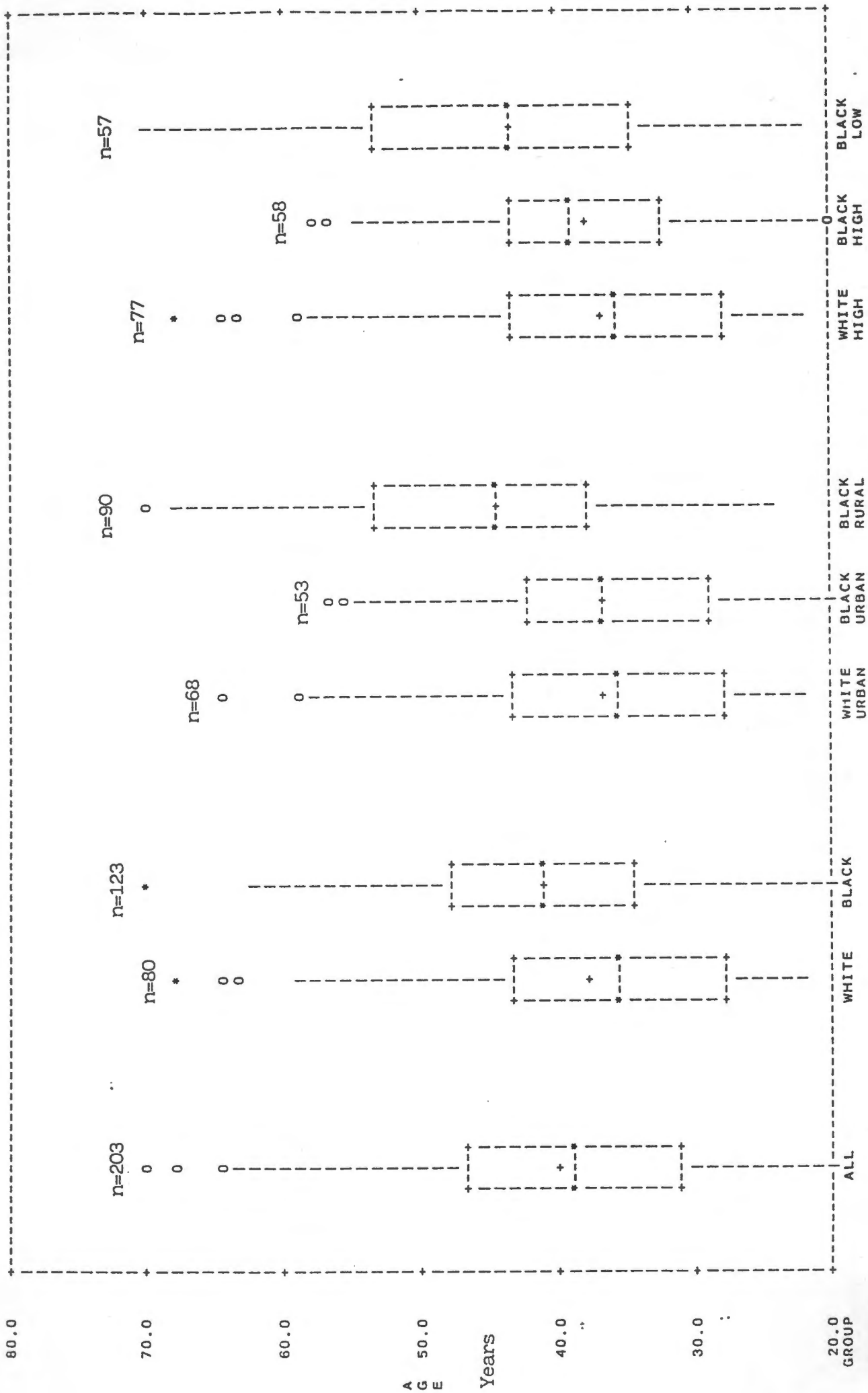


Fig 8 (XII) BOX PLOTS AGE DISTRIBUTION (HEALTHY GROUP)

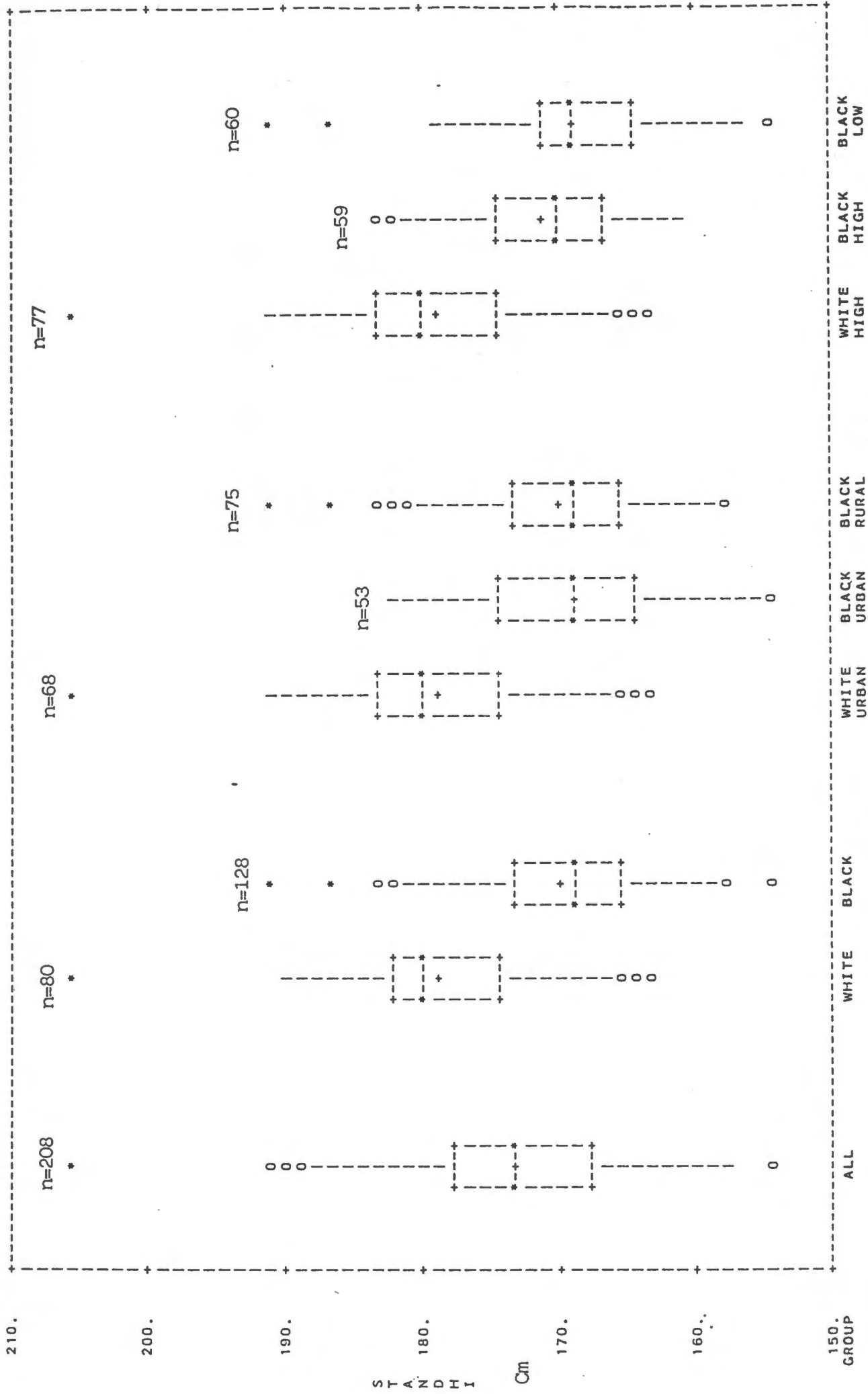


Fig 8 (XIV) BOX PLOTS - STANDING HEIGHT (HEALTHY GROUP)

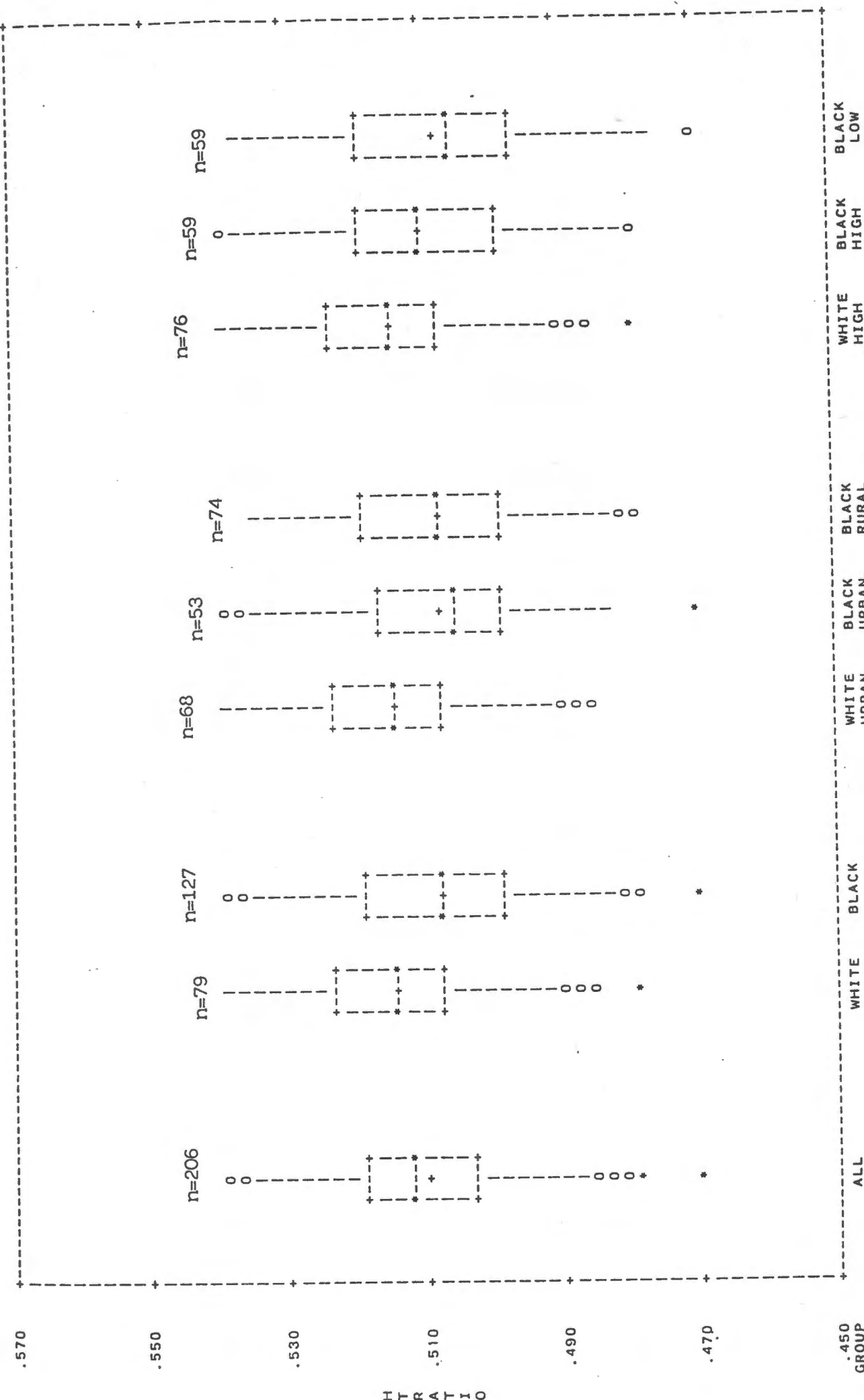


Fig 8 (XV) SITTING HEIGHT/STANDING HEIGHT RATIO (HEALTHY GROUP)

MEASUREMENT	All n = 208	Black n = 128	White n = 80	White Urban n = 68	Black Urban n = 53	Black Rural n = 75	White High n = 77	Black High n = 59	Black Low n = 60
FVC A/L M (L) SD R n	4.79 0.9 2.96-7.51 192	4.26 0.7 2.96-5.77 114	5.57 0.8 3.66-7.14 78	5.68 0.8 3.85-7.14 66	4.34 0.6 2.96-5.65 51	4.20 0.7 3.01-5.77 63	5.58 0.8 3.55-7.71 75	4.42 0.7 2.96-5.73 55	4.06 0.6 3.01-5.77 52
FEV ₁ A/L M (L) SD R n	4.09 0.8 2.25-6.31 n	3.57 0.6 2.37-4.96 n	4.41 0.7 2.25-6.31 n	4.50 0.7 2.76-6.11 n	3.72 0.6 2.37-4.96 n	3.46 0.6 2.08-4.71 n	4.60 0.7 2.25-6.31 n	3.72 0.6 2.37-4.96 n	3.42 0.6 2.40-4.70 n
FEV/FEV ₁ % M A/L SD R	83.42 5.9 61.6-100	84.04 6.0 61.6-100	81.47 5.9 61.3-93.5	82.69 5.7 69.1-94.6	83.74 5.8 71.2-94.3	82.81 6.2 61.6-100	82.40 5.9 63.4-94.6	82.16 6.1 93.68	83.05 5.42 73.9-94.3
FVC V/G M (L) SD R n	4.67 0.9 2.44-7.14 179	4.26 0.6 2.44-5.75 106	5.41 0.7 3.66-7.14 73	5.50 0.7 3.85-7.14 63	4.34 0.6 3.13-5.27 44	4.20 0.7 2.41-5.74 62	5.42 0.7 3.66-7.14 71	4.29 0.6 3.24-5.58 50	3.96 0.6 2.44-5.75 48
FEV ₁ V/G M (L) SD R	3.82 0.8 2.01-6.11	3.41 0.5 2.08-4.71	4.42 0.7 2.24-6.10	4.50 0.7 2.76-6.11	3.56 0.5 2.31-4.58	3.30 0.5 2.08-4.71	4.41 0.7 2.24-6.11	3.53 0.6 2.31-4.95	3.28 0.5 2.07-4.76
% FEV ₁ /FVC M V/G SD R	81.93 5.8 59.6-94.3	82.24 5.8 59.6-94.2	82.52 5.8 63.3-94.6	81.72 5.6 71.5-93.5	85.56 5.5 65.4-95.9	81.19 5.6 60-90.9	81.33 5.9 61.3-93.5	82.16 5.9 59.6-92.1	84.42 5.65 73.2-94.3

M = mean; SD = standard deviation; R = range

FVC = forced vital capacity; FEV₁ = forced expiratory volume in 1 sec; % = percentage

A/L = Autolink; V/G = Vitalograph

TABLE 8 (xxx): SPIROMETRIC MEASUREMENTS - HEALTHY GROUP

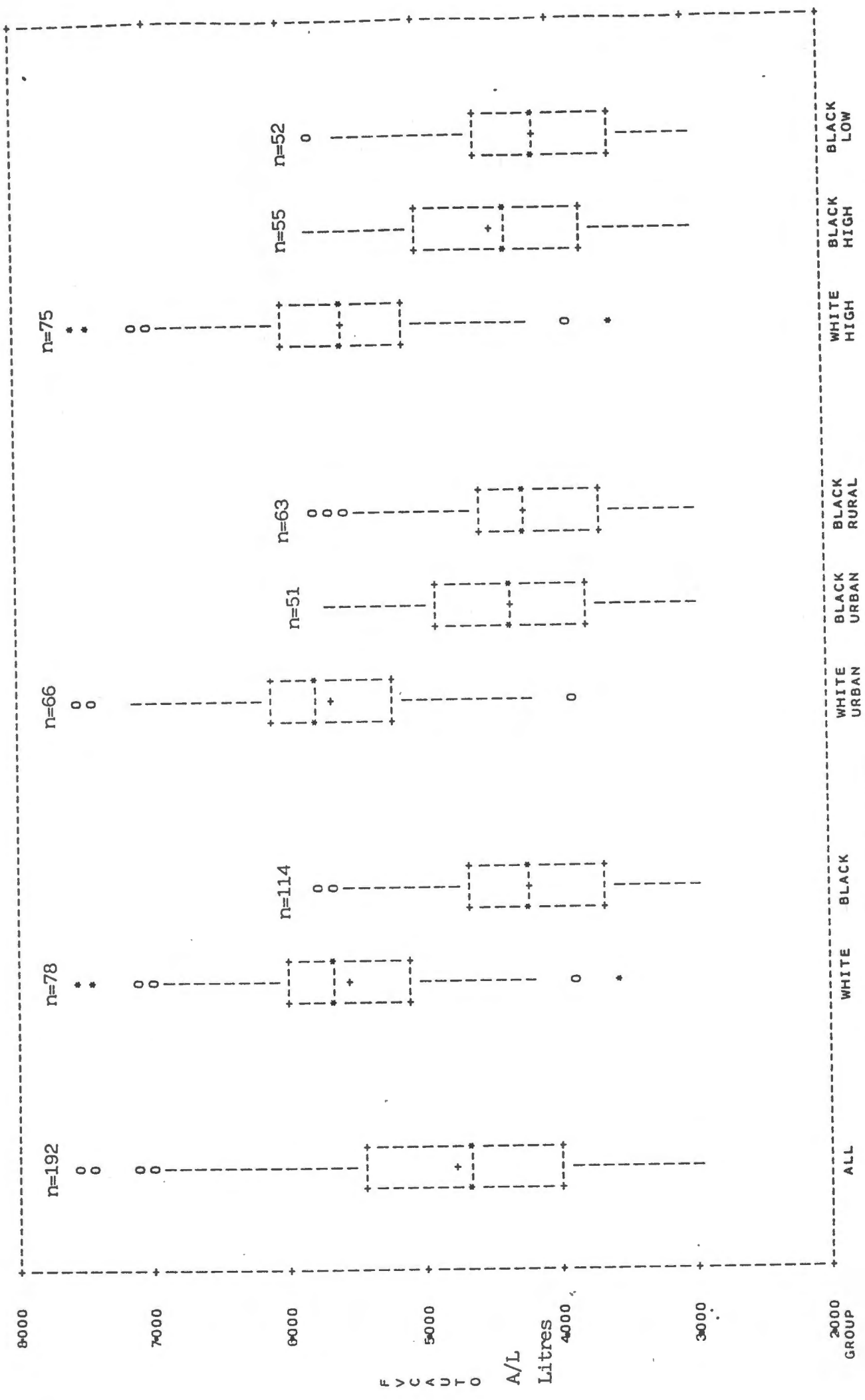


Fig 8 (XVI) BOX PLOTS - FVC (A/L) (HEALTHY GROUP)

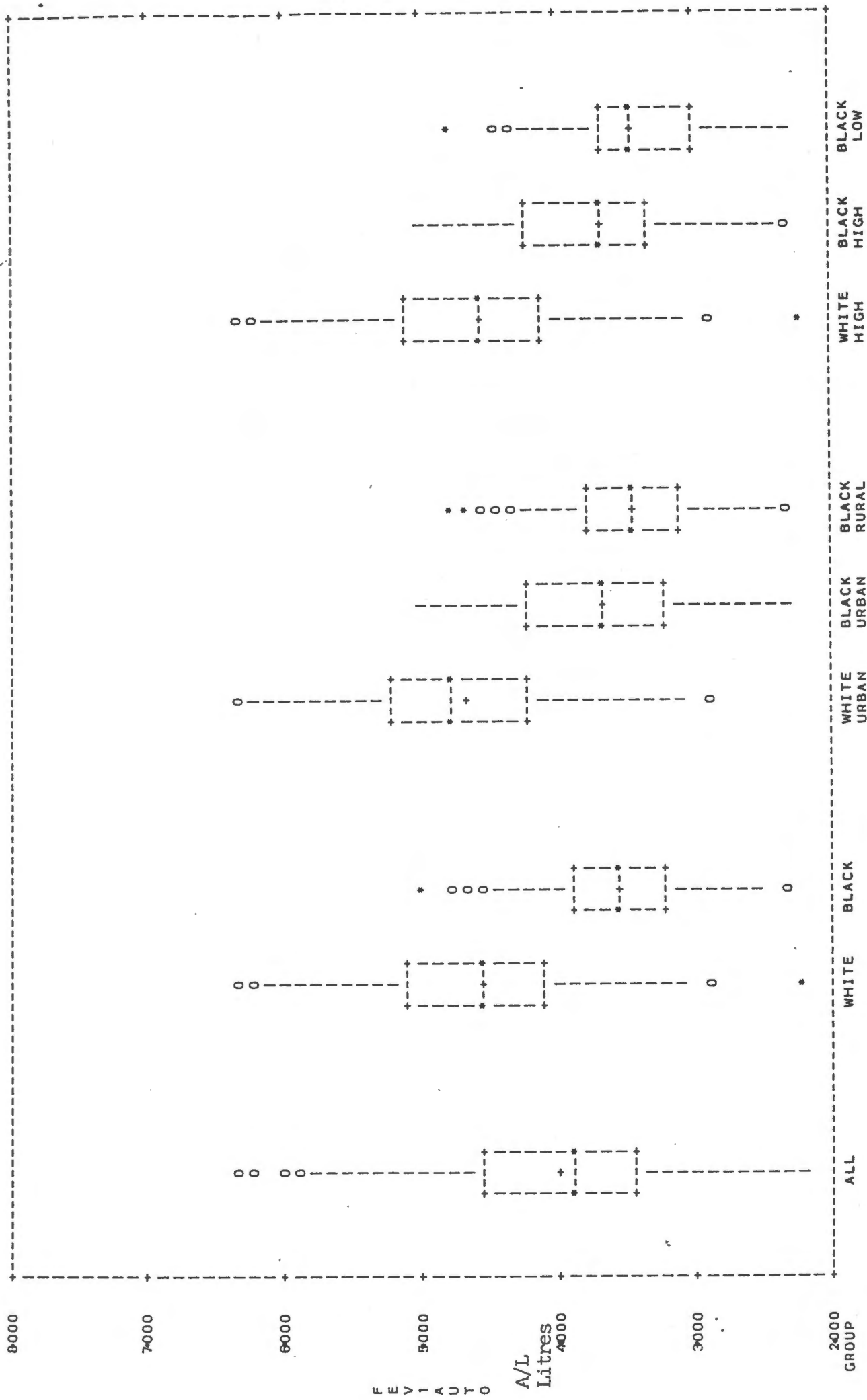


Fig 8 (XVII) - FEV1 (A/L) (HEALTHY GROUP)

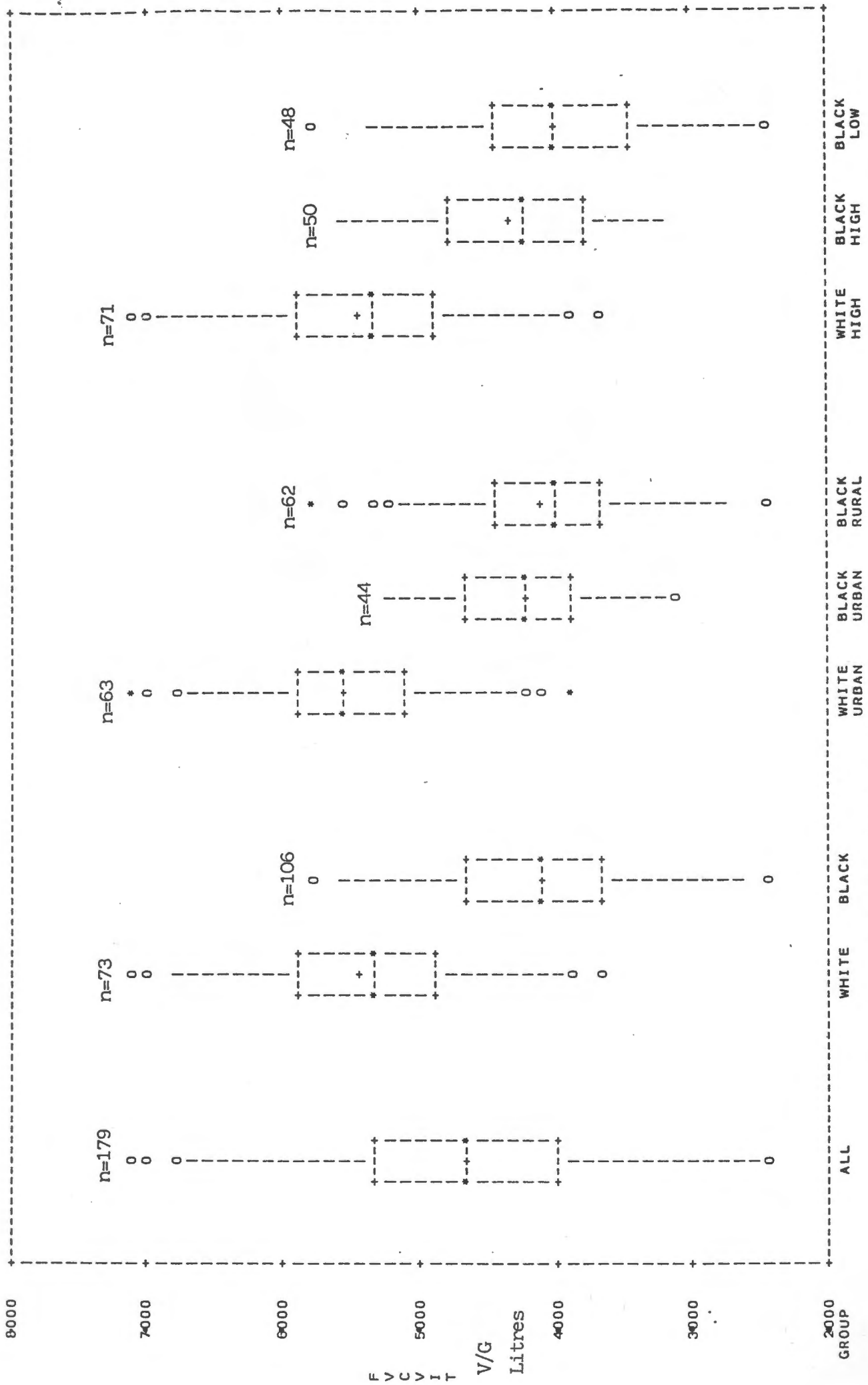


Fig 8 (XVIII) -- FVC (V/G) (HEALTHY GROUP)

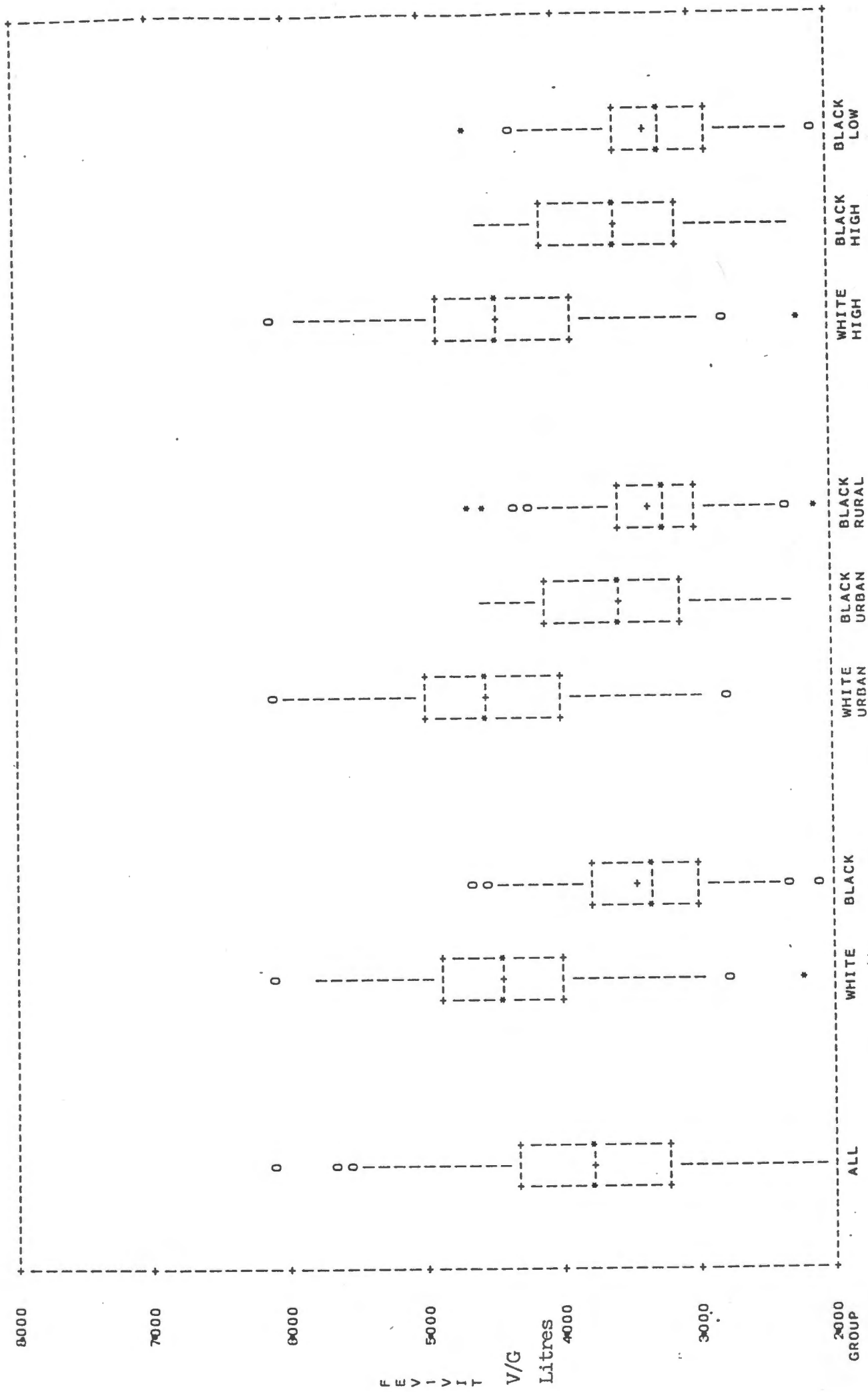


Fig 8 (XVIX) - FEV1 (V/G)

Comparison of the spirometric measurements obtained for the healthy population with the Vitalograph and Autolink demonstrated consistently higher measurements (160 ml mean for FVC; 211 ml (mean) for FEV₁, recorded by the Autolink (t test; $p = 0.001$ in each case). Similar differences were noted for both black and white groups. It was decided to perform a separate investigative analysis of the determinants of normal spirometric measurements on the sets of data obtained by the Vitalograph and Autolink.

In the following paragraphs the analysis of normal spirometric measurements and the results of multiple regression and covariance analysis will be presented.

The mean FVC measurements for the healthy population was 4.79L (Autolink) and 4.67L (Vitalograph). The FEV₁ measurements were 3.99L and 3.82L respectively. "White" men had a mean FVC of 5.7L (Autolink) and 5.42L (Vitalograph), whereas the average for "black" men was 4.26L (Autolink), 4.16L (Vitalograph). The respective mean FEV₁ measurements recorded were 4.61 (Autolink) and 4.42 (Vitalograph) and 3.58 (Autolink) and 3.41L (Vitalograph). These results must be interpreted in the light of the observation that the mean standing height and sitting heights for "whites" being 9.1 and 5.8 cm greater than that of blacks (t test; $p = 0.001$ and $p = 0.001$). The mean FEV₁/FVC ratio was 83.42 (Autolink) and 81.93 (Vitalograph). The ratio for blacks was 82.23% (Vitalograph) and 84.04% (Autolink) and that for whites was 81.47% and 82.52% respectively, with no significant difference being demonstrated (t test; $p = 0.383$ (Vitalograph) and $p = 0.093$ (Autolink). These differences are consistently demonstrated when the population is stratified initially by race and then by a social stratification indicator (e.g. place of birth, father's occupation) (see Table xxii).

The lung functions for the healthy group were adjusted for anthropometric difference to a sitting height of 88 cm, height ratio of 0.51 and age 40 years. These results are presented in Table 8 (xxxi) and Figures 8 (xx) - (xxiii). It will be seen that in all instances, the volumes (both FVC and FEV₁) for blacks were smaller than those for whites. The significance of these difference is explored in the section dealing with regression and covariance analysis.

MEASUREMENT LITRES	ALL n = 208	WHITES n = 80	BLACKS n = 128	WHITE URBAN n = 68	BLACK URBAN n = 53	BLACK RURAL n = 75	+WHITE HIGH n = 77	+BLACK HIGH n = 59	+BLACK LOW n = 60
FVC (A/L)									
M	4.71	4.90	4.57	4.93	4.52	4.62	4.89	4.53	4.54
SD	0.55	0.52	0.54	0.55	0.47	0.59	0.53	0.50	0.50
n	189*	77	112	66	51	61	74	54	51
FEV ₁ (A/L)									
M	3.92	4.08	3.82	4.11	3.81	3.82	4.06	3.78	3.81
SD	0.50	0.50	0.47	0.52	0.47	0.47	0.50	0.46	0.52
FVC (V/G)									
M	4.55	4.74	4.42	4.75	4.36	4.46	4.74	4.35	4.38
SD	0.54	0.49	0.53	0.51	0.46	0.58	0.50	0.51	0.52
N	178*	74	104	63	44	57	70	49	45
FEV ₁ (A/L)									
M	3.73	3.84	3.62	3.90	3.59	3.64	3.88	3.54	3.64
SD	0.49	0.49	0.46	0.50	0.44	0.48	0.49	0.45	0.47

* number in data set < that on Table due to effect of missing data regarding ages and anthropometric measurements.

V/G = Vitalograph; A/L = Autolink; M = Adjusted mean; SD = Adjusted standard deviation; n = number; + based on father's occupation

TABLE 8 (xxxi): ADJUSTED[±]-SPIROMETRIC MEASUREMENTS FOR HEALTHY GROUP

(+ Adjusted for age 40 year, sitting height 88 cm and height ratio 0.51)

8.9.3. Multiple regression analysis

The results of the regression analysis is presented in this section. The selection criterion for the subsets of independent variables which best predict the dependent variable was Mallows' CP. The amount of variance explained by these subsets is demonstrated by the R^2 value which is also stated. The R^2 was utilized mainly for the purposes of comparison with previous studies and was not used

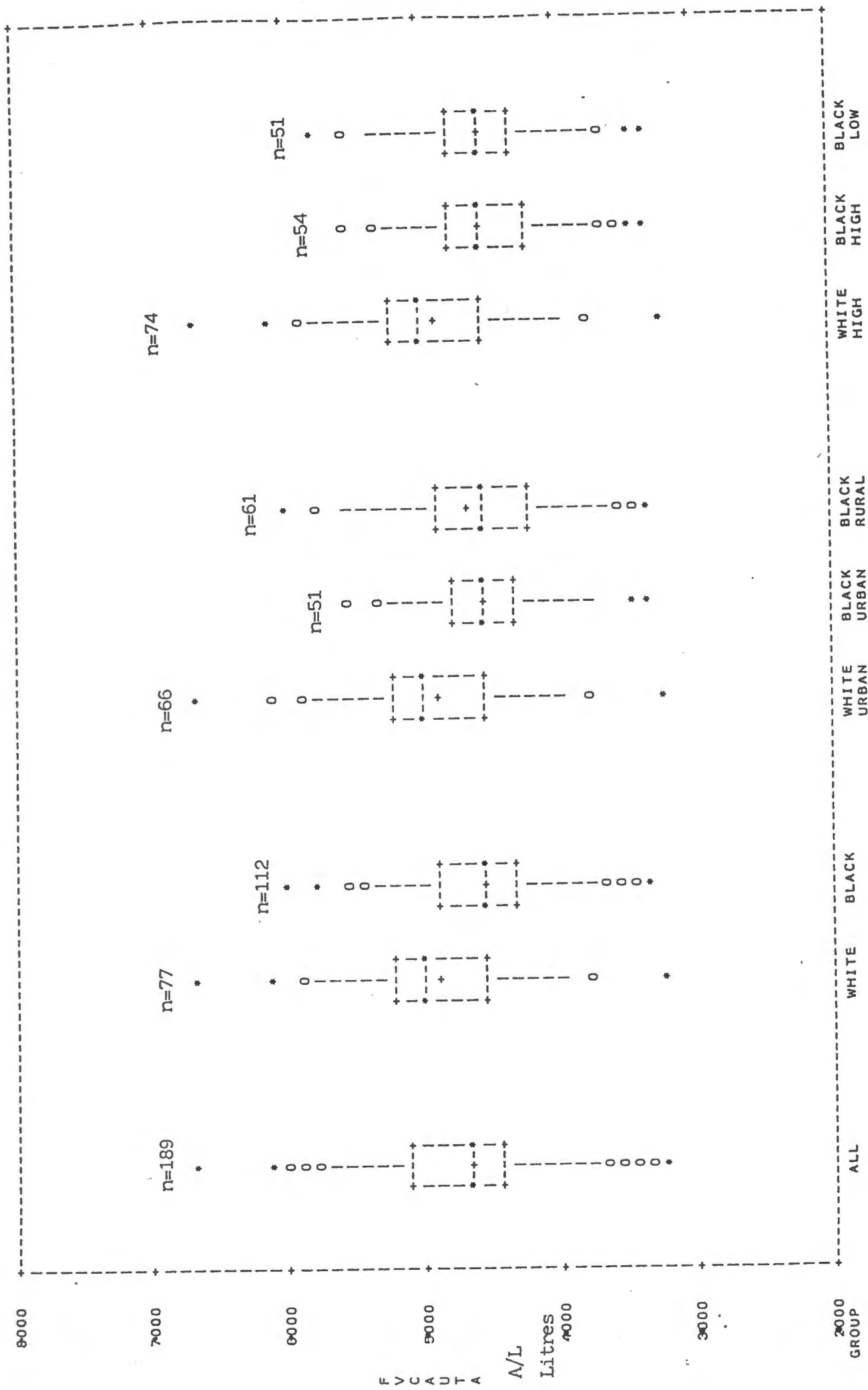


Fig 8 (XX) - ADJUSTED FVC (A/L) (HEALTHY GROUP)

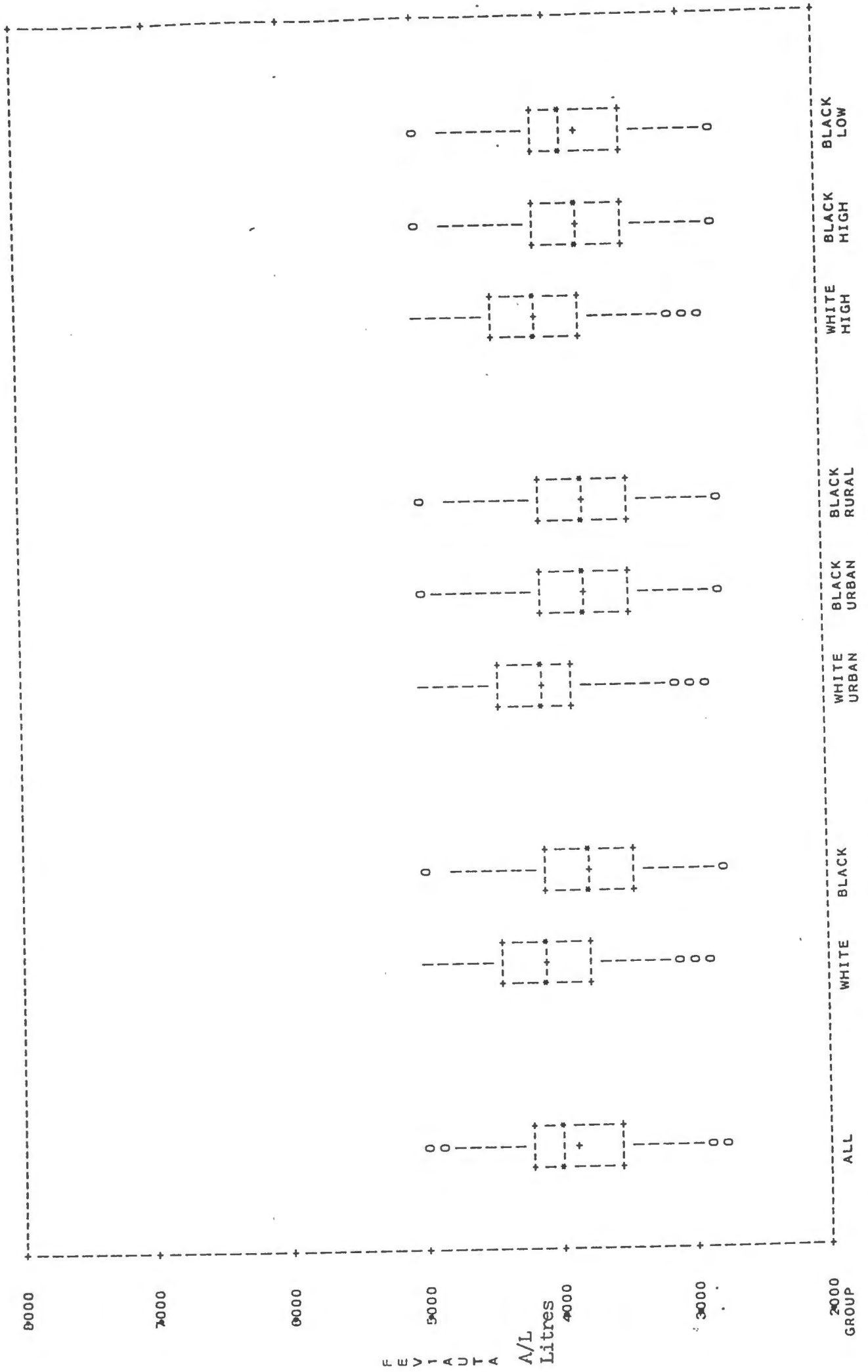


Fig 8 (XXI) BOX PLOTS-ADJUSTED FEV1 (A/L) (HEALTHY GROUP)

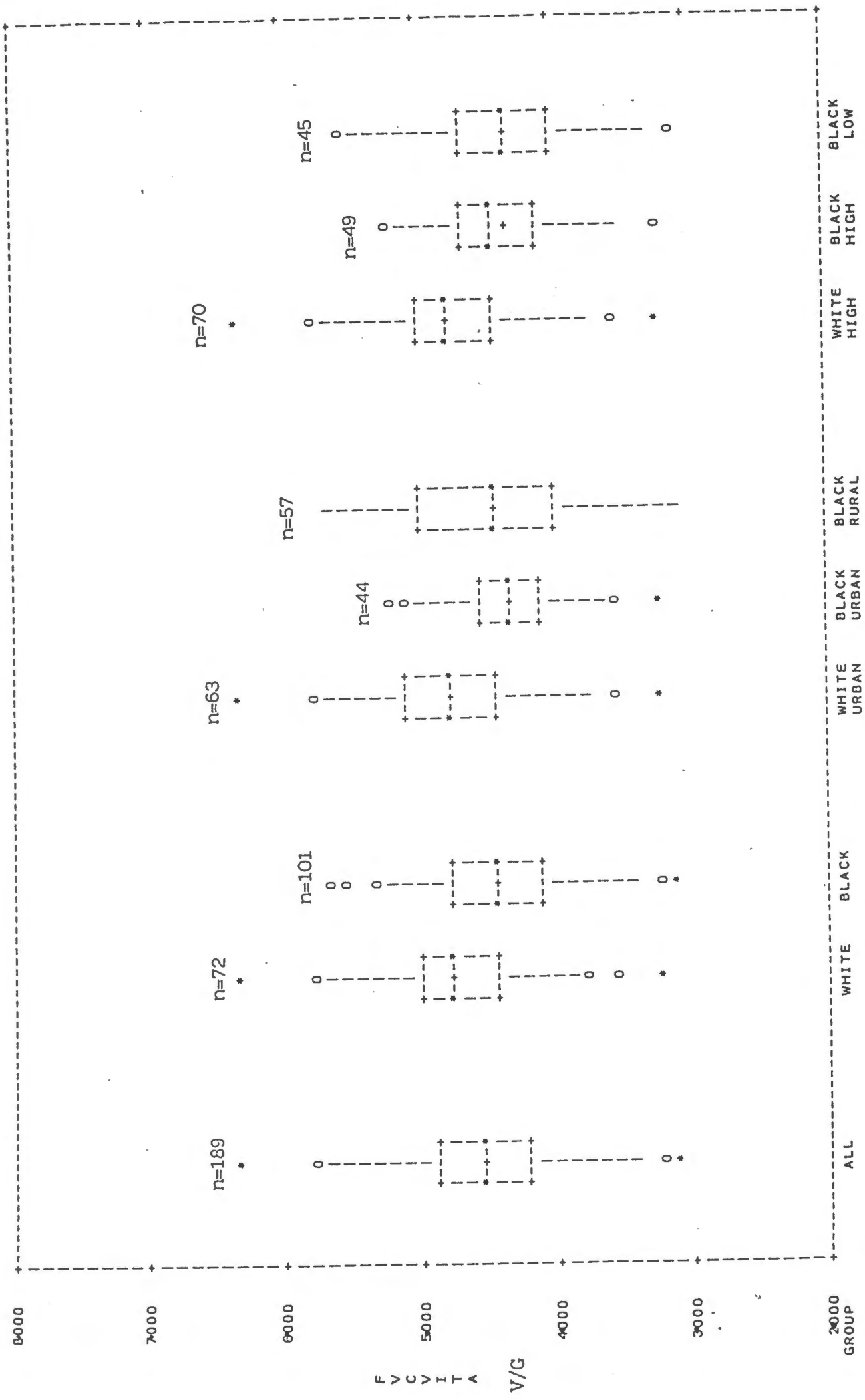


Fig 8 (XXII) BOX PLOTS ADJUSTED FVC (V/G)

for the purposes of selection in this investigation. Both these statistical concepts are described in Methods.

The regression analysis for vital capacity was performed on

- (i) all "healthy" subjects who performed spirometry,
- (ii) all "healthy" subjects who were 30 years of age or older,
- (iii) separately on all healthy "white" and "black" subjects,
- (iv) separately on all healthy "white" and "black" subjects 30 years of age or greater.

In all cases all subsets regression analysis was performed only on those subjects who had performed the measurement being investigated and whose data, with respect to the independent variables, was complete. The independent variables used in the analysis are summarized in the Table 8 (xxxii) below:

(A) <u>SOCIAL STRATIFICATION INDICATORS</u>
Place of birth
Current income
ADEC
Father's occupation
Race group
Childhood fuel*
(B) <u>ANTHROPOMETRIC MEASUREMENTS</u>
Standing height
Sitting height
Weight
Sitting/standing height ratio
Age

* used only in analysis of black groups)

TABLE 8 (xxxii): INDEPENDENT VARIABLES

As described in methods (Chapter 7) these indicators were identified prior to analysis being performed. In certain analyses the "race" variable was excluded in order to examine the effect this would have on the prediction of the dependent variable.

1. Vitalograph Study (FVC)

Tables 8 (xxxiii) (a) - (d) summarises the combinations of independent variables which best predict the dependent variable (Forced Vital Capacity) on regression analysis. The variables in the best subsets and their coefficients are presented for all subjects as well as for subjects older than 30 years of age. The anthropometric variables sitting height, age and height ratio appear in all of these combinations. The addition of the "race" variable (where black = 1 and white = 2) to these subsets of variables leads to the best combination with a low Mallows' CP (2.07 with 4 variables) and R^2 of 0.73. Where the race variable is excluded, however, the best subset includes the combination adult stratification indicator ADEC or childhood stratification indicator father's occupation. This subset of 4 variables, with a CP of 4.84, also explains 69% of the variance. Similar results are obtained when the analysis groups are limited to those subjects ≥ 30 years of age. The combination of sitting height and height ratio is found to be equally important when the analysis is performed for race groups separately. The amount of variance explained is lower when analysis is performed separately on the racial groups; 62% for whites and only 43% for blacks.

GROUP	VARIABLES			INDEPENDENT VARIABLES				I/CEPT	R ² CP	
	Total No.	Best Subset	Race	Sit ht	Age	Ht ratio	+Race			
All Healthy n = 165	10	4	In	Sit ht 0.123	Age -0.028	Ht ratio -12.57	+Race 0.589	.409	.73	2.07
	9	4	Out	Sit ht 0.169	Age -0.028	Ht ratio -13.52	*ADEC -0.207		-1.59	.69
All Healthy ≥ 30 yrs n = 157	10	4	In	Sit ht 0.116	Age -0.027	Ht ratio -11.17	+Race 0.623	0.201	.68	3.16
	9	4	Out	Sit ht 0.143	Age -0.027	Ht ratio -12.27	*ADEC -0.346		-1.54	.64

+Race = 1 = black, 2 = white; *Adec = 1 = high, 2 = low

TABLE 8 (xxxiii) (a): BEST SUBSETS FOR FVC ADULT MALES (VITALOGRAPH STUDY)

GROUP	VARIABLES			INDEPENDENT VARIABLES				I/CEPT	R ² CP
	Total No.	Best Subset	Race	Sit ht	Age	Ht ratio	+ADEC		
"White" n = 71	9	4	N/A	Sit ht 0.123	Age -0.028	Ht ratio -13.35	+ADEC 0.567	-1.38	.62 5.59
"White" > 30 yrs n = 49	9	3	N/A	Sit ht 0.108	Age -0.033	Ht ratio -10.06		1.92	.57 1.92
"Black" n = 93	10	4	N/A	Sit ht 0.118	Age -0.023	Ht ratio -8.06	*Child Fuel -0.136	-0.87	.43 1.78
"Black" ≥ 30 yrs n = 75	10	4	N/A	Sit ht 0.141	Age -0.18	Ht ratio -13.70	Weight -0.009	0.288	.39 4.28

+ADEC = 1 = high, 2 = low; *Childhood fuel = 1 = electricity, 2 = wood/coal

TABLE 8 (xxxiii) (b): BEST SUBSETS FOR FVC - WHITE AND BLACK ADULT MALES SEPARATELY (VITALOGRAPH STUDY)

GROUP	VARIABLES			INDEPENDENT VARIABLES				I/CEPT	R ² CP
	Total No.	Best Subset	Race	Sit ht	Age	Ht ratio	+Race		
All Healthy n = 180	10	4	In	Sit ht 0.127	Age -0.034	Ht ratio -13.49	+Race 0.591	0.938	.75 3.14
	9	4	Out	Sit ht 0.166	Age -0.034	Ht ratio -14.71	Born -0.213	-0.825	.69 5.58
All Healthy ≥30 yrs n = 139	10	4	In	Sit ht 0.120	Age -0.032	Ht ratio -12.36	Race 0.613	0.827	.69 2.59
	9	4	Out	Sit ht 0.148	Age -0.032	Ht ratio -11.73	ADEC -0.306	-0.705	.65 3.91

+Race = 1 = black, 2 = white; ADEC = 1 = high, 2 = low

TABLE 8 (xxxiii) (c): BEST SUBSETS FOR FVC - ADULT MALES (AUTOLINK STUDY)

GROUP	VARIABLES			INDEPENDENT VARIABLES				I/CEPT	R ² CP	
	Total No.	Best Subset	Race	Sit ht	Age	Ht ratio				
"White" n = 79	10		N/A	Sit ht 0.123	Age -0.038	Ht ratio -16.08		3.91	.62	3.80
"White" ≥ 30 yrs n = 75	10	4	N/A	Sit ht 0.483	Age -0.028	Ht ratio -13.35	+ADEC 0.567	-1.38	.62	5.59
"Black" n = 105	10	4	N/A	Sit ht 0.118	Age -0.023	Ht ratio -8.06	*Fuel -0.136	-0.87	.43	1.78
"Black" ≥ 30 yrs n = 86	10	4	N/A	Sit ht 0.141	Age -0.18	Ht ratio -13.70	Weight -0.009	0.288	.39	4.28

+ADEC = 1 = high, 2 = low; *Childhood fuel = 1 = wood fire, 2 = electricity

**TABLE 8 (xxaiii) (d): BEST SUBSETS FOR FVC - WHITE AND BLACK MALES SEPARATELY:
(AUTOLINK STUDY)**

	Stand Height	Age	Intercept	R ²
VITALOGRAPH STUDY				
FVC Blacks	0.048	-0.024	-3.08	0.33
FVC Blacks \geq 30 years	0.048	-0.018	-3.311	0.28
FVC Whites	0.056	-0.031	-3.42	0.55
FVC Whites \geq 30 years	0.049	-0.035	-2.10	0.53
AUTOLINK STUDY				
FVC Blacks	0.053	-0.030	-3.54	0.38
FVC Blacks \geq 30 years	0.052	-0.024	-3.629	0.32
FVC Whites	0.056	-0.038	-3.07	0.57
FVC Whites \geq 30 years	0.053	-0.039	-2.37	0.55

TABLE 8 (xxxiii) (e): TRADITIONAL SUBSETS FOR FVC - ADULT MALES: VITALOGRAPH AND AUTOLINK STUDY

The combination of independent variables standing height and age (which is the currently favoured) explains only 62% of the variance of FVC when the entire group is studied (not tabulated). The associated CP 6.38 indicates the inadequacy of restricting prediction equations of FVC to these two variables alone being the basis of the prediction equation for FVC. When sitting height and race are added to standing height and age, CP improves to 2.37 (R² of 73%). The combination of standing height and age has R² of 0.55 and CP of 8.11 for the FVC of whites and R² of 0.33 for the CP 11.12 FVC of blacks (see Table 8 (xxxiii) (e)). Both of these fall short of the best combinations demonstrated for these groups which include sitting height + height ratio.

2. Autolink Study (FVC)

The results of regression analysis results for the dependent variable FVC Autolink were similar to those for FVC Vitalograph (see Table 8 (xxxiii) (c) and (d)). In all cases, however, the R² values are higher for the Autolink measurements. Analysis including the race variable accounts for 75% of the variance (with a CP 3.14), but the exclusion of this variable still results in 69% of the variance being explained (with CP 5.58).

The best subsets for prediction of FVC Autolink also include sitting height + height ratio. The regression analysis for whites is the only one which includes standing height in addition to these two anthropometric measurements.

The subsets consisting of standing height and age (not tabulated) explains only 64% of the variance with an inadequate CP of 12.74 when the whole groups is analysed. The same combination explains only 38% of variance for blacks and 57% for whites, with poor CP values of 8.81 and 12.53 respectively (see Table 8 (xxxiii) (e)).

3. VITALOGRAPH AND AUTOLINK STUDY (FEV₁)

The independent variables which best predict FEV₁ are summarised in Table xxxiv (a) - (d). The independent variables included in the best subsets for prediction of FEV₁ did not show the same consistency as was demonstrated for FVC. The amount of variance explained as indicated by the R² is also not as good. In the regression analysis of all healthy subjects, sitting height, age and height ratio are the anthropometric measurements included in the best subsets. The addition of the race variable results in 70% of the variance being explained with good predictability implied by the CP of 2.19. The exclusion of the race variable results in the social stratification indicator ADEC being included with 64% of the variance explained with an associated CP of 3.38. These results are similar for both Autolink and Vitalograph measured functions.

In the analysis of race separated groups, standing height and age are the best anthropometric determinants on their own for whites, as is the current accepted practice. Subsets with these 2 variables alone account for only 25% (Vitalograph) and 27% (Autolink) of the variance compared with 53% and 51% explained by the best subsets for whites 30 years of age or greater. The CP values 12.8 and 8.2 obtained for standing height and age alone precludes their selection as the best prediction variables. In most cases, an additional stratification variable such as place of birth or current income improves the R² and CP

values considerably as demonstrated in Tables 8 (xxxiv) (c) - (e). In "blacks" sitting height, age and height ratio are again the best anthropometric variables. The only exception to this is the regression of FEV₁ (Autolink) in the black group spanning all ages in which standing height and age alone give rise to the best subset with CP 1.01.

4. Traditional analysis

For purposes of comparison with previous investigations the best subsets incorporating standing height and age are presented in Tables 8 (xxxii) (e) and xxxiv (e). Subsets all explain a similar amount of the variance as the best subsets described above. In all cases inferior CP values were obtained which indicates their inferior predictive ability.

GROUP	VARIABLES			INDEPENDENT VARIABLES				I/CEPT	R ² CP	
	Total No.	Best Subset	Race							
All Healthy n = 165	10	4	In	Sit ht 0.086	Age -0.032	Ht Ratio -8.249	Race 0.485	0.957	0.70	2.19
All Healthy n = 165	9	4	Out	Sit ht 0.112	Age -0.034	Ht Ratio -8.160	ADEC -0.218	-0.285	0.64	3.30
Healthy ≥ 30 years n = 124	10	3	In	Sit ht 0.076	Age -0.034	Ht Ratio -7.512	Race 0.542	1.382	0.61	0.78
All healthy ≥ 30 years n = 124	9	3	Out	Sit Ht 0.090	Age -0.032	ADEC -0.294		-2.546	0.56	0.74

TABLE 8 (xxxiv) (a): BEST SUBSETS FOR FEV₁ - ADULT MALES (VITALOGRAPH STUDY)

GROUP	VARIABLES			INDEPENDENT VARIABLES					I/CEPT	R ² CP	
	Total No.	Best Subset	Race								
All Healthy n = 180	10	5	In	Sit ht	Age	Ht Ratio	Race	Born	1.664	0.69	2.15
				0.092	-0.034	-9.537	0.485	-0.127			
All n = 180	9	4	Out	Sit ht	Age	Ht Ratio	ADEC		0.668	0.66	3.37
				0.113	-0.036	-9.535	-0.266				
Healthy ≥ 30 years n = 139	10	4	In	Sit ht	Age	Ht Ratio	Race		1.997	0.61	0.50
				0.082	-0.034	-9.094	0.521				
n = 139	9	4	Out	Sit Ht	Age	Ht Ratio	ADEC		0.951	0.58	0.74
				0.102	-0.033	-8.457	-0.319				

TABLE 8 (xxxiv) (b): BEST SUBSETS FOR FEV1 - ADULT MALES (AUTOLINK STUDY)

GROUP	VARIABLES			INDEPENDENT VARIABLES				I/CEPT	R ² CP	
	Total No.	Best Subset	Race							
Whites n = 71	9	4	N/A	St ht 0.050	Weight -0.008	Age -0.033	Born -0.316	-2.373	0.59	3.04
White ≥ 30 years n = 49	9	2	N/A	St ht 0.035	Age -0.042			-0.248	0.53	0.80
Black n = 94	10	4	N/A	Sit ht 0.068	Age -0.029	ADEC -0.304	R Income 0.337	-1.443	0.41	0.82
Black ≥ 30 years n = 75	10	3	N/A	Sit Ht 0.073	Age -0.023	Ht Ratio -7.348		1.64	0.28	1.33

**TABLE 8 (xxxiv) (c): BEST SUBSETS FOR FEV1 - WHITE AND BLACK MALES SEPARATELY
(VITALOGRAPH STUDY)**

GROUP	VARIABLES			INDEPENDENT VARIABLES			I/CEPT	R ² CP	
	Total No.	Best Subset	Race						
Whites n = 53	9	3	N/A	St ht 0.043	Age -0.038	Born -0.336	-1.243	0.58	5.09
White ≥ 30 years n = 53	9	3	N/A	St ht 0.036	Age -0.036	R Income -0.535	-0.017	0.52	2.32
Black n = 86	10	2	N/A	St ht 0.036	Age -0.032		-1.18	0.55	1.01
Black ≥ 30 years n = 105	10	3	N/A	Sit Ht 0.088	Age -0.032	Ht Ratio -8.084	1.418	0.54	1.72

**TABLE 8 (xxxiv) (d): BEST SUBSETS FOR FEV1 - WHITE AND BLACK MALES SEPARATELY
(AUTOLINK STUDY)**

	Standing Height	Age	Intercept	R ²
VITALOGRAPH STUDY				
FEV ₁ Blacks	0.029	-0.027	-0.535	0.35
FEV ₁ Blacks ≥ 30 years	0.029	-0.021	-0.722	0.24
FEV ₁ Whites	0.042	-0.036	-1.84	0.25
FEV ₁ Whites ≥ 30 years	0.035	-0.042	-0.248	0.53
AUTOLINK STUDY				
FEV ₁ Blacks	0.036	-0.032	-1.18	0.33
FEV ₁ Blacks ≥ 30 years	0.033	-0.024	-1.151	0.40
FEV ₁ Whites	0.042	-0.038	-1.45	0.27
FEV ₁ Whites ≥ 30 years	0.037	-0.043	-0.474	0.51

**TABLE 8 (xxxiv) (e): TRADITIONAL SUBSETS FOR FEV₁ - ADULT MALES: VITALOGRAPH AND
AUTOLINK STUDY**

8.9.4 Group Comparative Studies

The results of group comparative studies, by means of analysis of covariance are presented below. On the basis of the regression analysis the lung functions were adjusted for sitting height, age and height ratio for purposes of this analysis. This analysis was performed separately on lung function results measured by either the Autolink or Vitalograph. Results were similar and only the results for the Autolink measured forced vital capacity determinations are presented. The results are presented in Figures 8 (xx) - (xxii). The slopes of each covariate was ensured at the 5% level prior to the interpretation of the covariance of analysis.

1. COMPARISON OF GROUPS STRATIFIED BY SOCIAL STRATIFICATION INDICATORS (SSI)

(a) SSI: Race

The mean FVC, adjusted for height ratio 0.51, sitting height 88.51 cm and age 39.5 years, for blacks was 4.57L and for whites 5.15 L, which was statistically significantly different (t test; $p = 0.001$). The mean adjusted FVC for blacks was thus 11% smaller than that of whites.

(b) SSI: Race and Father's Occupation

Forced vital capacity was adjusted to a sitting height 89.2 cm, height ratio 0.51 and age 38.9 years. The largest adjusted forced vital capacity is demonstrated for the high white group 5.11 L, which is significantly larger than the high black group 4.42L (t test; $p = 0.001$) and the low black group 4.33 L (t test; $p = 0.001$). No difference is demonstrated between the black groups (t test; $p = 0.39$).

(c) Race and Place of Birth

The largest FVC (adjusted for sitting height 85.5 cm, age 36.65 years and height ratio 0.51) was demonstrated for whites born in an urban area, 5.14L. This is significantly larger than the mean adjusted FVC for blacks born in an urban area 4.43 L (t test; $p = 0.001$) or those born in rural areas 4.35 L (t test; $p = 0.001$). There is no significant difference demonstrated for the adjusted forced vital capacity between blacks born in an urban or rural area (t test; $p = 0.47$).

SSI	Group	n	Group mean (L)	Adjusted mean (L)	(Std error)	Probabilities		
						1	2	3
Race	1 White	77	5.58	5.15	0.71	1		
	2 Black	112	4.27	4.57	0.56	0.001	1	-
Father's occupation	1 White high	71	5.42	5.11	0.68	1		
	2 Black high	49	4.30	4.42	0.82	0.001	1	
	3 Black low	46	3.97	4.33	0.75	0.001	0.39	1
Place of birth	1 White urban	63	5.50	5.14	0.70	1		
	2 Black urban	44	4.10	4.43	0.83	0.001	1	
	3 Black rural	57	4.25	4.35	0.75	0.001	0.47	1

**TABLE 8 (xxxv): FVC ANALYSIS OF COVARIANCE SOCIAL STRATIFICATION GROUPS
WITHIN RACE GROUPS**

2. COMPARISON OF GROUPS STRATIFIED BY OTHER SSI WITHIN THE BLACK GROUP ONLY

(a) SSI: Current Income

The FVC adjusted for a sitting height of 86.14 cm, height ratio of 0.51 and age of 40.67 years is 4.30 L for the higher black group and 4.26 for the lower group. There is no significant difference between these two groups (t test; $p = 0.51$).

(b) SSI: School Education

The adjusted FVC (for sitting height 85.89; height ratio 0.51 and age 34.9 years) is 4.27L for the higher social stratification group and 4.25 L for the lower group; with no statistical difference demonstrated (t test; $p = 0.878$).

SSI	Group	n	Group mean (L)	Adjusted mean (L)	(Std error)	Probabilities	
						1	2
School education	1 High Black	39	4.42	4.27	0.90	1	
	2 Low Black	72	4.18	4.257	0.64	0.88	1
Current Income	1 High Black	29	4.30	4.22	0.99	1	
	2 Low Black	83	4.26	4.29	0.58	0.51	1

TABLE 8 (xxxvi): FVC ANALYSIS OF COVARIANCE SOCIAL STRATIFICATION GROUPS WITHIN THE BLACK HEALTHY GROUP

3. COMPARISON OF GROUPS WITHIN SPECIFIC AGE CATEGORIES STRATIFIED BY SSI

(a) Comparison of race differences within different age intervals

This analysis was performed on the data obtained from both healthy never-smokers and otherwise healthy previous smokers. In the 25-34 year age group FVC was adjusted for sitting height 88.61, height ratio 0.51 and age 29.5 years, while in the age group 35-45 years the measurements were adjusted to sitting height 88.62, height ratio 0.51 and age 39.5 years. No significant difference was demonstrated in either age category between these two smoking categories for either blacks (t test; $p = 0.46$) or whites (t test; $p = 0.32$).

Group	n	Group mean (L)	Adjusted mean (L)	(Std error)	Probabilities		
					1	2	3
25 - 34 years							
* 1 White high	22	5.42	5.42	1.21	1		
* 2 Black high	18	4.56	4.65	1.26	0.001	1	
* 3 Black low	17	4.17	4.55	1.67	0.001	0.61	1
35 - 45 years							
* 1 White high	24	5.46	5.22	1.29	1		
* 2 Black high	21	4.27	4.44	1.31	0.002	1	
* 3 Black low	18	4.10	4.27	1.69	0.001	0.42	1

* Stratification indicator = Father's occupation

TABLE 8 (xxxvii): FVC: ANALYSIS OF COVARIANCE COMPARISON OF STRATIFIED GROUPS IN TWO AGE CATEGORIES

(b) SSI: Father's Occupation

In both age categories the results are similar. The largest mean (adjusted for sitting height 88.62, height ratio 0.51 and age 29.5 years) in the 25-34 year age group was that obtained for the high white group (as defined by father's occupation) 5.42 L. This was significantly larger than the adjusted mean FVC for the high black group 4.65 (t test; $p = 0.001$) and the low black group 4.53 (t test; $p = 0.001$). In the older age category (35 - 45 years) again the highest mean FVC (adjusted to sitting height 88.62, height ratio 0.51 and age 39.5 years) was also obtained for the high white group (5.22 L). This was also significantly larger than the mean FVC for the high black group which was 4.44 L (t test; $p = 0.002$) and for the low black group 4.10 L (t test; $p = 0.001$).

Group	n	Group mean (L)	Adjusted mean (L)	(Std error)	Probabilities	
					1	2
25 - 34 years						
1 White	28	5.68	5.42	1.19	1	
2 Black	35	4.28	4.44	1.29	0.001	1
35 - 45 years						
1 White	27	5.46	5.22	1.21	1	
2 Black	39	4.10	4.27	1.21	0.001	1

TABLE 8 (xxxviii): FVC: ANALYSIS OF COVARIANCE COMPARISON OF "RACE GROUPS IN TWO AGE CATEGORIES

(c) Race Groups

The mean FVC (adjusted for age 29.5 years, sitting height 89.1 cm and height ratio 0.51) for the whites in the age category 25-34 years is 5.42 L, which was significantly larger than that obtained for blacks in the same category (t test; $p = 0.001$). In the older age group the mean FVC (adjusted for age 39.5 years, sitting height 88.6 cm and height ratio 0.51) was again obtained for white males 5.22 L, which was significantly larger than that obtained for the blacks which was 4.27 L (t test; $p = 0.001$).

8.10 RESULTS OF TRANSFER TEST (TLCO_{SB}) SURVEY8.10.1 Description of Transfer Testing Performed

Of the total 796 subjects in the survey carbon monoxide gas transfer (TLCO_{SB}) was measured in 436 (54.75%) subjects. 358 (45%) subjects were unable to perform this measurement due to the pressure of work and 2 (0.25%) subjects did not perform any tests. 424 (97.25%) measurements met both ATS and ITS standards for acceptability; 12 (2.75%) were rejected. Of the total 510 black subjects in the survey 244 (47.8%) acceptable traces were obtained and in the case of whites there were 180 (62.9%). These results are shown in Fig 8 (xxiv).

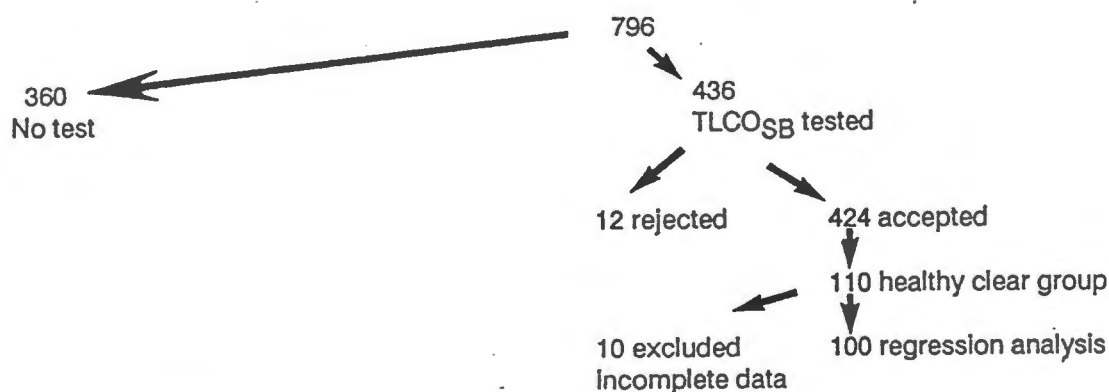


FIG 8 (xxiv): FLOW DIAGRAM OF TLCO_{SB} STUDY

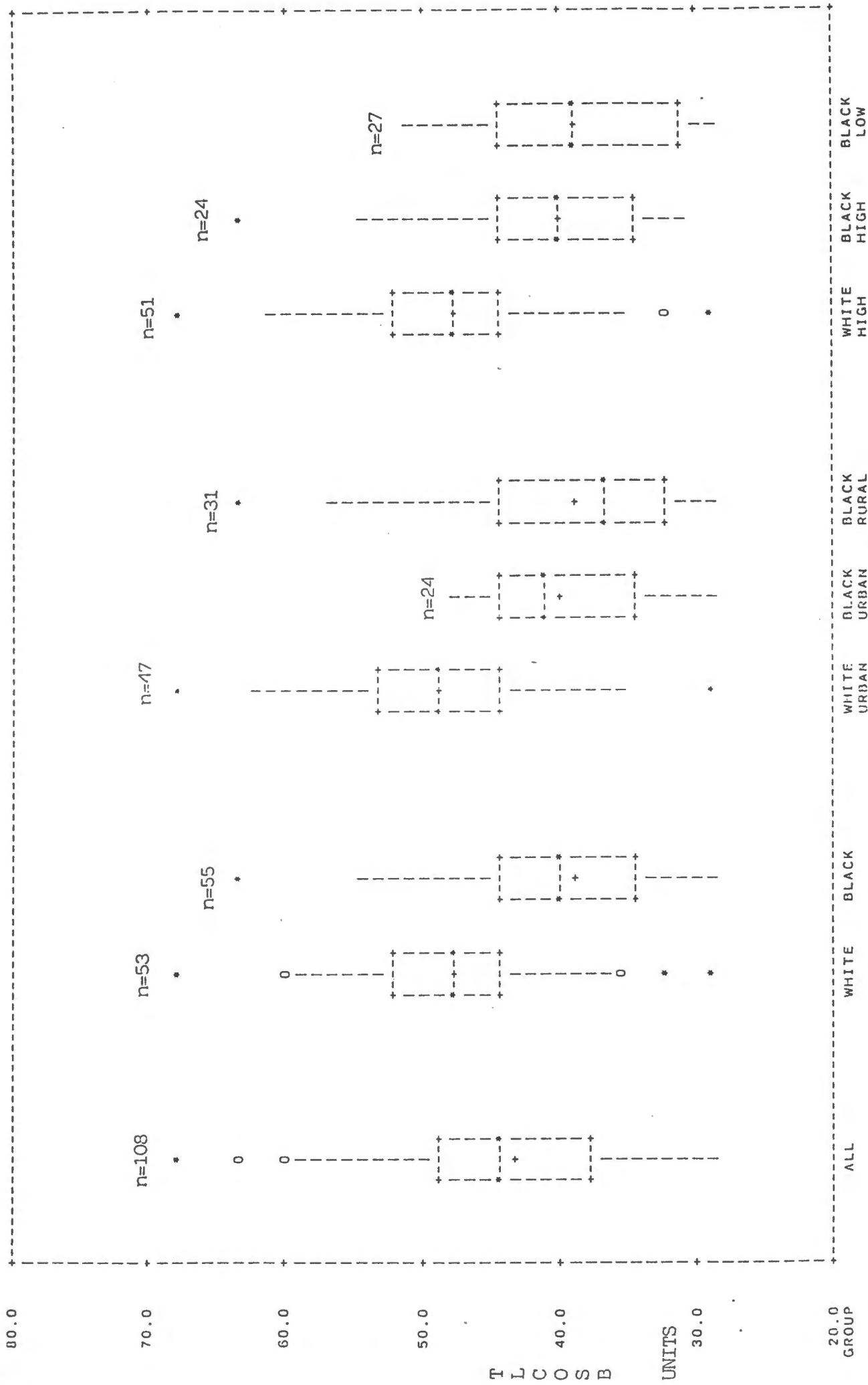


Fig 8 (XXV): BOX PLOTS TFCOSB (HEALTHY GROUP)

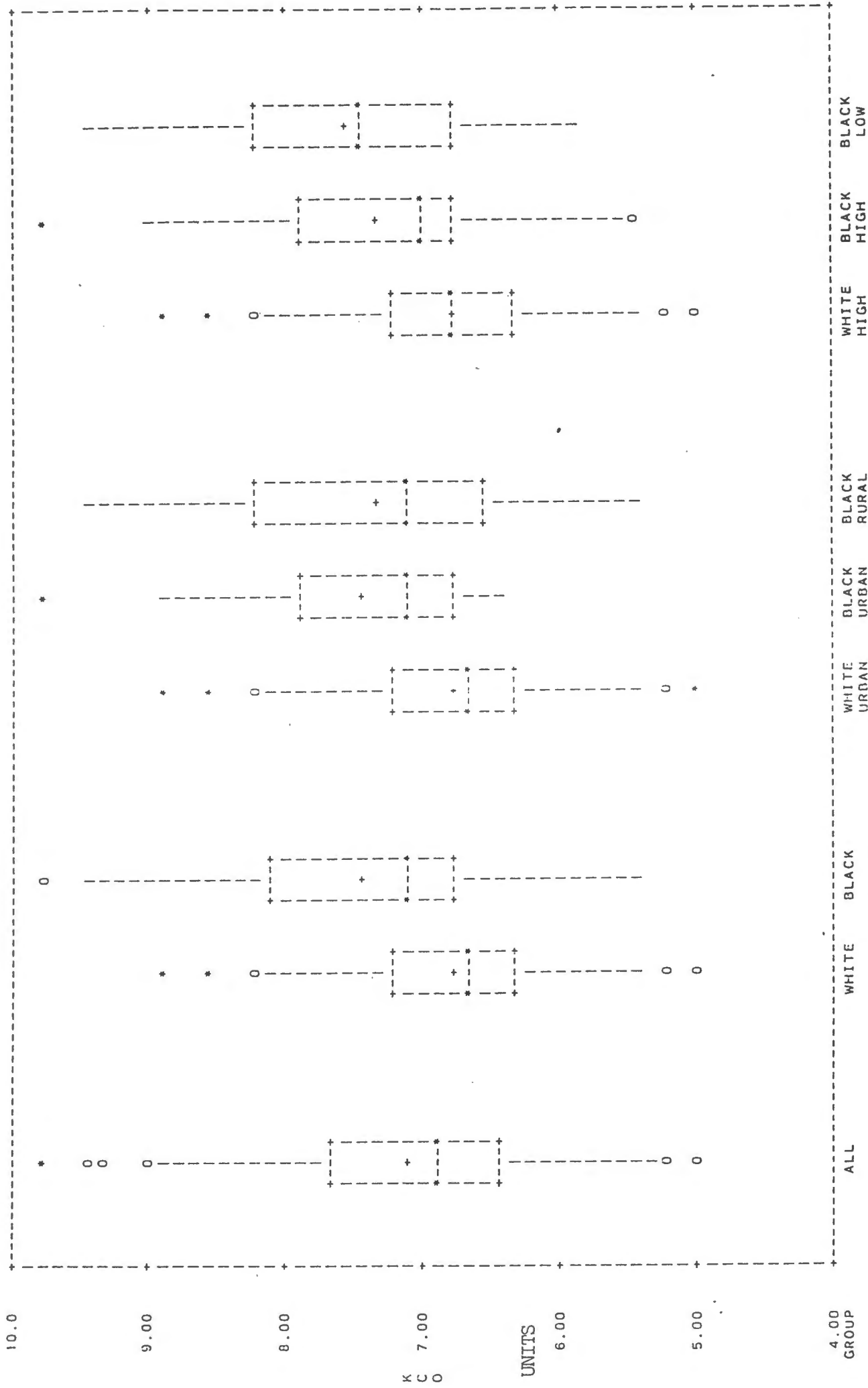


Fig 8 (XXVI) BOX PLOTS KCO (HEALTHY GROUP)

	All n = 110	Black n = 55	White n = 55	White Urban n = 49	Black Urban n = 24	Black Rural n = 31	High White n = 51	High Black n = 24	Low Black n = 31
TLCO_{SB}									
Mean	43.44	39.28	47.92	48.52	39.81	38.82	48.03	40.33	38.56
SD	8.9	6.85	7.09	7.01	5.56	7.77	7.21	7.21	6.67
Range	28.4-67.5	28.4-62.8	29.2-67.5	29.2-67.5	28.5-48.0	28.5-62.8	29.2-67.5	30.6-62.9	28.4-51.1
n	108	55	53	47	24	31	51	24	27
KCO									
Mean	6.8	7.1	6.3	6.3	7.2	6.89	6.33	7.16	7.0
SD	1.11	1.05	1.03	1.05	0.97	1.12	1.02	1.02	1.07
Range	2.7-9.9	3.2-9.9	2.7-8.8	2.7-8.9	4.4-9.7	3.24-9.2	2.7-8.9	4.4-9.9	3.2-9.4

TABLE 8 (XL): TRANSFER TEST RESULTS - HEALTHY GROUP

8.10.3 TLCO_{SB} Regression Analysis

The results of the regression analysis are summarised in Table 8 (XLI). 100 subjects were included in the regression analysis. 10 subjects were excluded because their data sets were not complete (5 because ages were in dispute, 3 had rejected transfer tests and 2 missing data for other variables).

The independent variables included in the regression analysis were the same as those outlined for the analysis of spirometry (see Table 8 (xxxii)). The subsets of variables that best explained the dependent variable TLCO_{SB} were:

GROUP	VARIABLES			INDEPENDENT VARIABLES (Variable Coefficient)	I/CEPT	CP	R ²
	Total No.	Best Subsets (n)	Race				
Normal subjects	10	3	In	Stand ht 0.439 Age -3.05 +Race 2.88	25.38	1.30	0.55
n = 100	10	3	In	Sit ht 1.08 Age -0.32 Ht ratio -102.8	11.49	1.67	0.55
	10	4	In	Sit ht 0.100 Age -0.31 Ht ratio -105.98 Income -1.83	24.56	1.89	0.57

+Race = 1 = black, 2 = white

TABLE 8 (XLI): BEST SUBSETS - TLCO_{SB}

These three subsets of variables give rise to regression equations which are similar in the explanation of the variance and have similar CP values. The last two equations exchange standing height for sitting height and height ratio and exclude the variable race without markedly affecting the CP value. The best equation which includes a 4th variable (that of the social stratification indicator "current income") in addition, also explains 2% more of the variance. The last two equations do not include race as an independent variable despite the fact that this analysis is performed on a combined group composed of 55 black and 55 white subjects.

8.10.4 TLCO_{SB} Group Comparative Analysis

The TLCO_{SB} measurements for the healthy group adjusted to sitting height 88 cm, height ratio 0.51 and age 40 years, showed no significant difference between the groups. These results are examined more closely in the paragraphs below and summarised in Table 8 (XLii) and Figure 8 (xxvii).

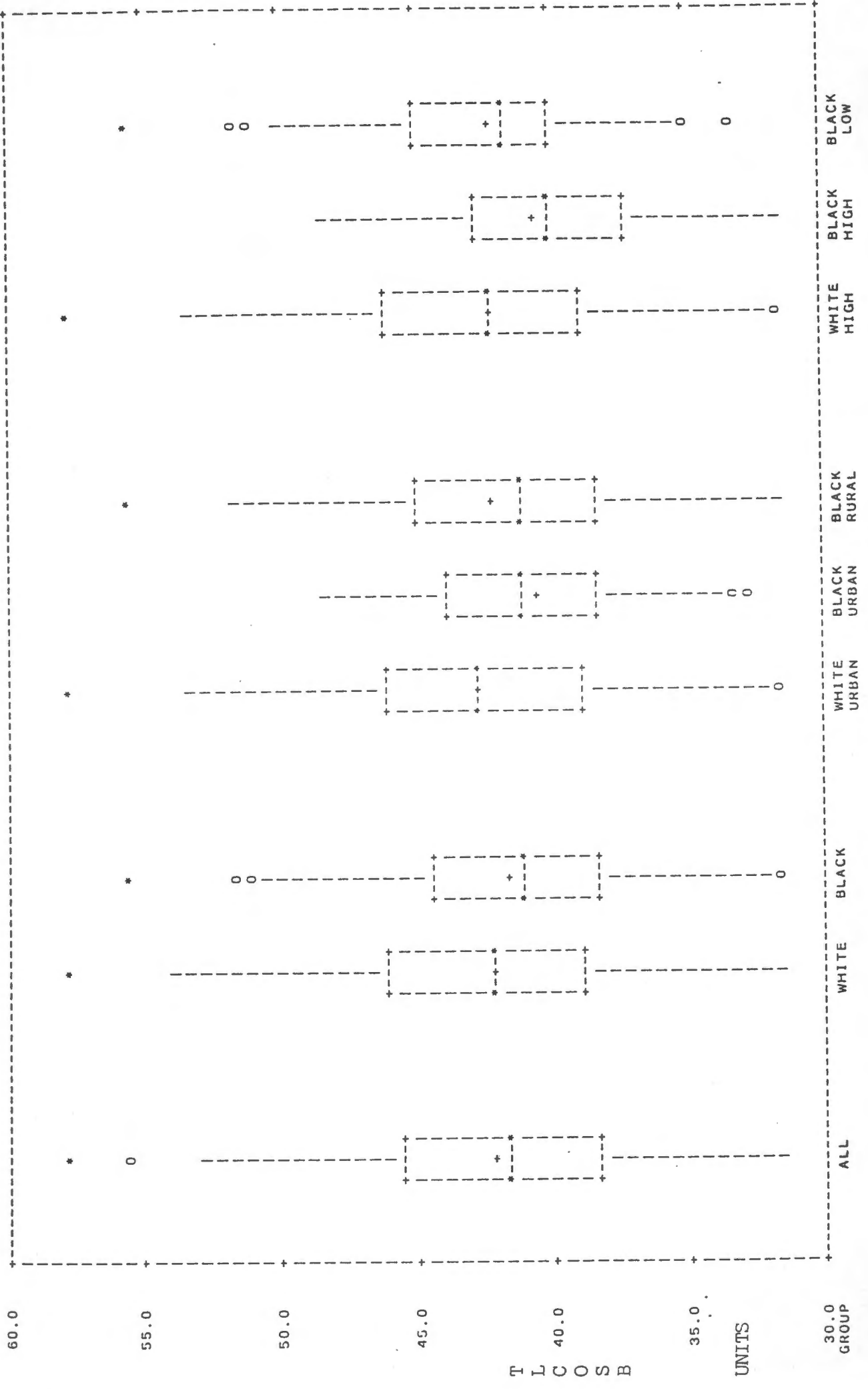


Fig 8 (XXVII) ADJUSTED TLCOSB (HEALTHY GROUP)

	ALL n = 110	WHITE n = 55	BLACK n = 55	WHITE URBAN n = 49	BLACK URBAN n = 24	BLACK RURAL n = 31	HIGH WHITE n = 51	HIGH BLACK n = 24	LOW BLACK n = 32
Adjusted M	42.03	42.46	41.61	42.78	40.66	42.40	42.44	40.64	42.32
TLCO _{SB} SD	5.39	4.94	5.82	5.02	4.57	6.66	4.89	6.46	5.52
n	105	52	53	47	24	29	50	24	25

TABLE 8 (XLii): ADJUSTED (SITTING HEIGHT, AGE, HEIGHT RATIO) TLCO_{SB} HEALTHY GROUP

1. Social Stratification Indicator: Race

Groups Compared	No.	Stand Ht (m)	Age (yrs)	Sit ht	Ht ratio	Measured TLCO _{SB} ml mm Hg	Adjusted TLCO _{SB}	Std error
Black	53	1.69	41.2			39.38	42.26	0.86
White	52	1.79	36.3			47.96	45.01	0.87
Black	53		41.3	86.1	0.51	39.38	42.57	0.83
White	52		36.3	92.7	0.57	47.96	44.57	0.82

TABLE 8 (XLiii): TLCO_{SB} COMPARISON ANALYSIS: "RACE"

When TLCO_{SB} is adjusted for the differences in standing height and age (Table 8 (XLiii)), a significant difference is demonstrated between the two "race groups" (t test; $p = 0.048$). The adjustment of TLCO_{SB} using the best independent variables identified in the regression analysis sitting height and height ratio results in no significant difference being demonstrated (t test; $p = 0.23$) between the two race groups.

2. Other social stratification group comparisons

Comparison of $TLCO_{SB}$ measurements between different social stratification groups shows no significant differences between these groups. The results are summarised in the table below:

STRATIFICATION INDICATOR	GROUPS COMPARED	N	AGE	SITTING HEIGHT	HEIGHT RATIO	MEASURED $TLCO_{SB}$	ADJUSTED $TLOC_{SB}$
"Fathers occupation"	High Wt	50	36.27	92.78	0.52	47.99	44.52
	High B	24	39.0	87.33	0.51	40.33	42.28
	Low B	24	43.0	85.20	0.51	38.72	43.80
"Current income"	High Wt	48	36.60	92.75	0.52	47.81	44.45
	High B	20	39.05	87.05	0.51	42.09	43.72
	Low B	33	42.63	85.48	0.51	37.73	41.62

TABLE 8 (XLiv): $TLCO_{SB}$ COMPARISON ANALYSIS: SOCIAL STRATIFICATION GROUPS

When the healthy population is stratified by the indicator father's occupation no significant difference is demonstrated for $TLCO_{SB}$ measurements for high white and high black groups (t test; $p = 0.20$); high white and low black groups (t test; $p = 0.35$) and high black and low black groups (t test; $p = 0.29$). When the same population is stratified using the indicator current income, a gradation in $TLCO_{SB}$ is suggested. The highest adjusted measurements was recorded for the high white group $44.45 \text{ ml mm Hg}^{-1}$, followed by the high black group $43.72 \text{ ml mm Hg}^{-1}$ and then the black low group $41.26 \text{ ml mm Hg}^{-1}$. These differences are not, however, statistically significant; high white vs high black ($p = 0.07$) high black vs low black ($p = 0.18$) and high white vs low black ($p = 0.09$).

3. Comparison of smoking groups

In order to examine the chronic effects of smoking on $TLCO_{SB}$, the group was expanded to include otherwise healthy individuals within the three smoking categories. The results of this analysis is displayed in the table below:

SMOKING CATEGORY	N	AGE	SITTING HEIGHT	HEIGHT RATIO	MEASURED $TLCO_{SB}$	ADJUSTED $TLOC_{SB}$
Never	105	38.80	89.36	0.51	43.62	43.62
Previous	54	40.94	89.56	0.51	41.02	41.23
Current	102	37.19	88.02	0.51	38.81	38.97

TABLE 8 (XLv): $TLCO_{SB}$ COMPARISON ANALYSIS: SMOKING GROUP

$TLCO_{SB}$ is significantly higher in never smokers compared with both previous ($p = 0.019$) and current smokers ($p = 0.001$) $TLCO_{SB}$ of previous smokers is also significantly higher than those of current smokers ($p = 0.023$).

8.10.5 Haemoglobin Estimation Survey

Haemoglobin estimations were obtained on 123 healthy participants; 88 blacks and 35 whites. The results are summarised in Table 8 (XLvi) below:

HAEMOGLOBIN	GROUP		
	WHITE	BLACK	COMBINED
Mean	15.96	15.60	15.70
SD	1.45	0.95	1.12
Median	15.3	15.60	15.7
n	35	88	123

TABLE 8 (XLvi): HAEMOGLOBIN ESTIMATIONS

An analysis of covariance in which haemoglobin was corrected for age demonstrated no significant difference between black and white haemoglobin estimations (t test; $p = 0.18$).

8.11 TOTAL LUNG CAPACITY SURVEY

8.11.1 Description of Total Lung Capacity Measurements Performed

Total lung capacity (Helium dilution method) was measured in all 80 subjects randomly selected for this aspect of the survey; this included 43 black and 37 white subjects (see Fig 8 (xxviii)).

TOTAL LUNG CAPACITY

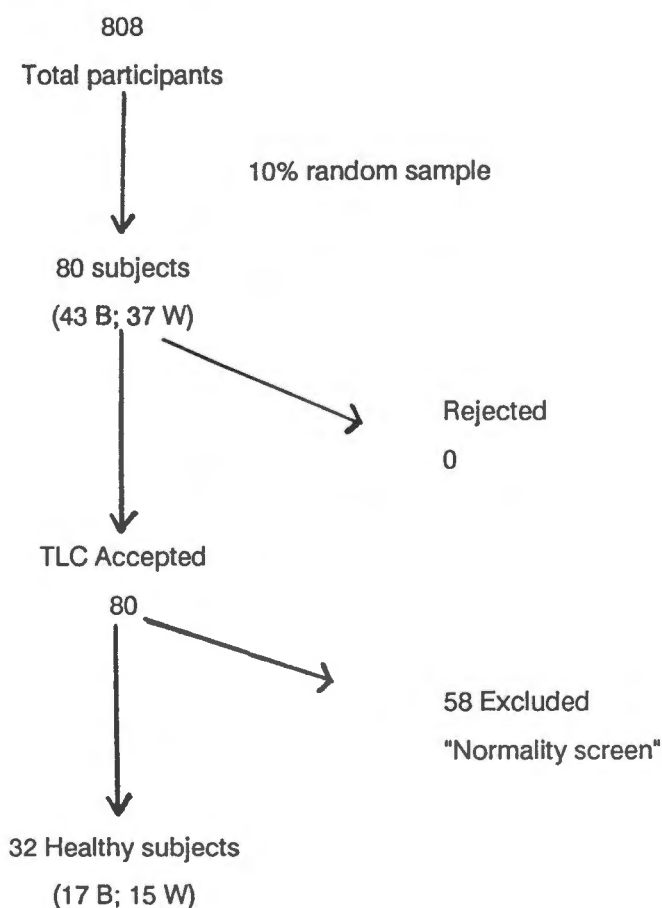


FIG. 8 (xxviii): FLOW DIAGRAM TOTAL LUNG CAPACITY SURVEY

8.11.2 TLC Measurements - Healthy Group

The mean age and anthropometric measurements of the 32 healthy individuals who had acceptable TLC measurements is summarised in Table 8 (XLvii) and Figure 8 (xxix) below:

MEASUREMENT	GROUP		
	TOTAL GROUP n = 32	BLACK n = 17	WHITE n = 15
Age (years)	37.6 (11.7)	35.5 (13.0)	40 (9.8)
Stand ht (cm)	175.6 (8.1)	179.8 (5.8)	170.9 (7.77)
Sit ht (cm)	89.7 (4.6)	92.6 (3.3)	86.3 (3.3)
Height ratio	0.5 (0.1)	0.51 (3.3)	0.51 (0.01)
TLC (L)	6.8 (1.2)	5.85 (0.78)	7.68 (0.77)

TABLE 8 (XLvii): TOTAL LUNG CAPACITY: PROFILE OF HEALTHY GROUP

8.11.3 TLC Regression Analysis

Due to the small number of healthy subjects results of only the regression analysis performed on the healthy group as a whole and not for any subgroups are presented. The independent variables selected for this analysis were age, weight, standing height, sitting height, height ratio and race. The best subsets are presented in Table 8 (XLviii).

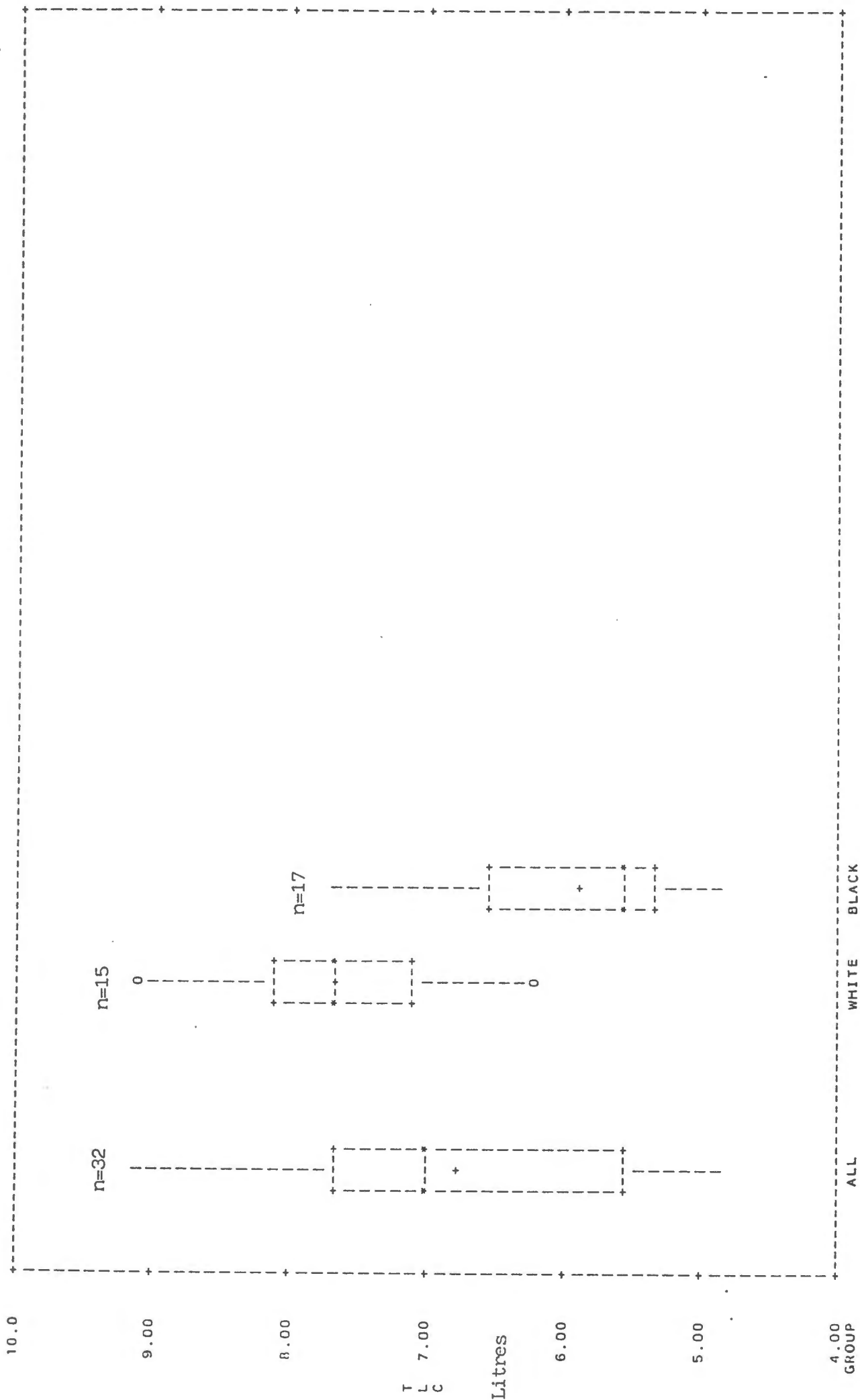


FIGURE 3 (XXVIX) - BOX PLOTS TOTAL LUNG CAPACITY (HEALTHY GROUP)

GROUP	VARIABLES			INDEPENDENT VARIABLES (Variable Coefficient)	I/CEPT	CP	R ²
	Total No.	Best Subsets (n)	Race				
Normal subjects n = 32	6	3	In	Stand ht Age +Race 0.87 10.67 0.96	-15.33	2.8	0.79
	6	3	In	Sit ht Age Ht ratio 0.17 18.91 0.95	-0.15	2.97	0.79

+Race = 1 = black, 2 = white

TABLE 8 (XLvii): BEST SUBSETS - TOTAL LUNG CAPACITY

Examination of standardised residuals and Cook's distance identified a significant outlier. Re-analysis often excluding the outlier showed that the best subset identified was the following:

Stand ht	+	Ht Ratio	+	Race	+	Intercept	R ²	CP
0.10		11.67		0.74		-17.63	0.83	3.67

The improved Mallows CP and R² of this subset was associated with an improved fit of the predicted measurements.

CHAPTER 9

9. DISCUSSION

9.1 INTRODUCTION

The need for quantitative information on the determinants of normal lung function, with particular reference to anthropometric and social stratification factors is well recognised. This Chapter will:

1. Examine the aims, methods, results and conclusions drawn from this study.
2. Examine the extent to which the conclusions can be substantiated.
3. Assess the extent to which the study met the aims it set out to achieve.
4. Propose new hypotheses.
5. Make recommendations for the use of prediction equations in:
 - (a) future research
 - (b) clinical practice
 - (c) preventative medicine
 - (d) legislation.

9.2 AIMS, OBJECTIVES AND CONCLUSIONS OF THE STUDY

The aim of the investigation was to collect data on the lung function (spirometric and gas transfer) of normal South African males. The specific objectives were to

- (a) identify social stratification indicators that may be used to identify sub-groups within a population and to determine the influence these indicators have on lung function;
- (b) to determine which anthropometric measurements influence lung function and to examine their relationship with social stratification influences;
- (c) to derive prediction equations for normal healthy adults.

The information collected in this investigation could be further used in order to determine the validity of currently accepted predicted normal values of lung function tests for different race groups, enhance the understanding of the determinants of normal lung function and to provide normal values for use in

clinical, epidemiological and occupational health evaluations. The purpose of this section is to review the important aspects of the methodology so that the validity of the results and conclusions drawn may be determined.

The study design was essentially that of a cross-sectional analytic study. Different groups were identified and the relationships between different factors examined. The study was concerned with identifying factors which could be regarded as important determinants of lung function. It was initially anticipated that a group comparison study, comparing a group of black middle class men with a similar group of white middle class men and a group of black lower class men would be feasible. It later became apparent that a group comparison study might be complicated by difficulties arising from the complexities of group definitions. These complexities included:

- (1) social stratification indicators are poorly understood;
- (2) a great deal of overlap exists between social stratification indicators;
- (3) analysis of childhood social stratification indicators demonstrated a different profile to that suggested by adult indicators in the feasibility study, and
- (4) the concept of "race", and in particular its relationship to social stratification is complex.

For this reason the objectives were broadened so that the investigation included:

- (1) a cross-sectional study of spirometry, gas transfer and lung volumes;
- (2) a cross-sectional study of current (adulthood) social stratification;
- (3) a retrospective study of childhood social stratification and
- (4) group comparison studies of lung function, social stratification and anthropometric measurements.

1. The lung function survey was a cross-sectional study in which spirometry and gas transfer was measured on all participants and, where time permitted, $TLCO_{5B}$ was measured. The equipment used and the methodology employed to collect the data adhered strictly to both the

most recent American Thoracic and Intermountain Thoracic Societies' recommendations^{30,51,52}. Analysis of the lung function data (the dependent variable) and their determinants (the independent variable) was undertaken using a very rigid multiple linear regression technique²⁷⁸. The analysis was performed on a "normal" sub-group. The normality screen resulted in the exclusion of subjects in whom

- (i) a chest radiograph abnormality (other than calcific speckles) was present,
- (ii) a frequent cough and/or sputum production and/or a history of chronic bronchitis was present,
- (iii) a history of attacks of wheezing that induced shortness of breath and/or a diagnosis of asthma were present,
- (iv) a history of severe chest infection with cough productive of sputum requiring bed rest for three weeks or more, and/or previously diagnosed pneumonia was present,
- (v) a diagnosed history of chronic bronchitis/emphysema/bronchiectasis/cardiac failure was present,
- (vi) radiographic evidence of cardiomegaly with features suggestive of cardiac failure was present (but not those in whom only cardiomegaly alone was noted),
- (vii) a previous history of pulmonary tuberculosis or suspected active disease,
- (viii) an acute respiratory infection on the day of the survey,
- (ix) an occupational history including work in a mine or quarry or foundry or grain mill or other environment with chemical fumes or gas or dust was present,
- (x) a positive smoking history was recorded (certain analyses were, however, performed on healthy, smoking categories and these will be discussed later),
- (xi) a history of previous chest injury or surgery was present.

Due to the relatively small subgroups within the healthy population the regression analysis was performed also on an extended data set which included smokers who were otherwise healthy. These results are not reported here, since the analysis showed no new relationships over those

found in the healthy never-smoking group. This analysis is also not preferred because of the unknown bias that may be introduced by including healthy smokers whose mean functions are not shown to differ significantly from those of non-smokers (see page 17, section 1.2.1 (e-iii)).

Since the aim of regression in lung function data is prediction, the usefulness of a particular regression equation was assessed by its mean squared error of prediction, namely the Cp criterion. The R^2 criterion was not used for subset selection, since a larger model will always have R^2 value equal and/or larger than that of a smaller model, so that the full model will always have the larger value of R^2 . All subsets were done using BMDP9R²⁷⁹, so that all models which are competitors for the "best model" could be seen. This approach was preferred to a stepwise procedure since stepwise procedures produce a single model as the best model, although this model may not include any of the variables in the actual best subset²⁸⁰. By doing all subsets regression one could see which models were competing with the best model.

Regression analysis demonstrated the importance of anthropometric measurements and age in predicting spirometric lung volumes. It was, however, clear that sitting height and the ratio sitting height/standing height were better predictors than the widely used standing height. Although anthropometric measurements (weight and chest circumference) and transformed variables (x^2 , $1/x$ etc) were investigated (although not reported here), they were not demonstrated to be of any value. The inclusion of this composite variable always improved the fit of the regression equation.

2 & 3 The social stratification studies were used to establish indicators of social stratification.

The first study was designed to establish the current social stratification of the population (a cross-sectional study). The second study was designed to determine the social stratification of the population during their childhood relying on recall of childhood circumstances. Since there

is no standardised approach regarding the determination of social stratification in either the medical or sociological literature, a separate social stratification investigation was included in the current survey. Nevertheless, for the purposes of the lung function survey, presumptive social stratification indicators were defined prior to statistical analysis, and their validity was assessed in a separate analysis. A statistical technique, usually used to assess interrater agreement, the Kappa interrater agreement²⁸¹ was utilized to identify the important indicators. These techniques allow the identification of "race" (skin colour), "place of birth" (urban vs rural), father's occupation (during subject's childhood), highest school education, current income, current occupation and a combination indicator (ADEC) as the most important indicators of social stratification. This will be discussed in more detail later in this chapter.

4. It was initially anticipated that three social stratification (SS) groups, as outlined above, would be identified. These groups would then allow group comparison studies, by means of analysis of covariance, in order to examine the relationship between social stratification and race on lung function.

However, there exists a very close relationship between these two concepts. "Race", currently regarded by many as a concept separate to social stratification, lacks a uniformly accepted definition (as discussed in Chapter 4). It became apparent, during the study, that a group of blacks who could be classified as currently middle class (by virtue of their income or occupation), were of lower SS than that of their white counterparts as assessed by other indicators of social stratification, including housing conditions and environment. In addition, their childhood social stratification status was generally much lower than their current social stratification position. In the light of these observations, it seemed naive to employ group comparison investigational techniques because discreet social stratification groups among the Black subjects could not be defined. For this reason it was decided that regression analysis should be the principal method of analysis.

The results of the group comparison studies demonstrated significant differences between high and low social stratification groups (however defined). This result is not unexpected if the hypothesis that social stratification factors influence lung function is correct. However, the demonstration of higher spirometric measurements for whites when compared to blacks makes it impossible to attribute these differences to the effects of social stratification if one accepts that "race" is an attribute which is wholly independent of SS. It could therefore be argued that the results confirm "race" (or genes) differences in spirometry. This latter interpretation may be simplistic and the arguments will be explored later on in this chapter.

The conclusions of this investigation are as follows:

1. The effect of "race" (as defined by skin colour) on lung function measurements could not be separated from the effects of SS; we conclude that the effects of "race" on lung function is not necessarily a genetic effect, but more probably a result of the close association between race and SS. Thus, "race" may be seen as a powerful indicator of SS. We argue that this effect is not confined to South Africa, but a world-wide phenomenon.
2. Other useful indicators include school education, father's occupation, current income, current occupation, place of birth (urban vs rural) and the composite indicator ADEC.
3. A black middle class, truly comparable to a white middle class, probably does not yet exist in South Africa. In this study, the group of blacks who currently earn the same income and work in the same positions as whites, were found to be fundamentally disadvantaged vis a vis other social stratification markers. This may be due either to the dominance of "race" as a social stratifier, or because we are now witnessing the early emergence of a higher social stratification black group.
4. Regression analysis demonstrates that indicators of social stratification are important determinants of mechanical lung function. Spirometric functions may be equally well predicted by the use of any of our presumptive social stratification indicators. Although "race" appears to be the most useful social stratification indicator, father's occupation and current income are almost equally good. It thus seems possible that the predictive value of "race" is due to the fact

that it is the best indicator of social stratification, rather than as an indicator of genetic factors influencing lung function.

5. The combination of sitting height and sitting height/standing height ratio are better determinants of mechanical lung function and gas transfer than the currently used standing height. This may mean that these indicators are better predictors of thoracic size.
6. There was no difference in the relationships of trunk to leg length in the different race groups in this study as demonstrated by the same sitting to standing height ratio (.51) in both these groups.
7. The Autolink computerised spirometer systematically measured significantly larger volumes for both FVC and FEV₁ compared with the Bellows and paper-trace Vitalograph^R (Model S.).

9.3 SUBSTANTIATION OF CONCLUSIONS

1. Introduction

This section of the discussion will evaluate the extent to which the conclusions drawn may be substantiated. In order that the conclusions be accepted, the results from which they are drawn should be valid and reliable. In addition, the conclusions should be consistent with all the data of the present study and they should be weighed against previously published findings.

Validity is defined as the closeness of results to the true or real situation. Lack of validity is described as bias which may arise from many sources²⁸². The major sources of variation include sampling and measurement biases. Reliability (reproducibility) is defined as the closeness of repeated measurements to one another. Lack of reliability also results in variation (due to lack of precision). Variation may occur from two major sources, sampling and measurement, as a result of random errors in these two spheres. The following paragraphs will discuss the validity and reliability of the results obtained in the current investigation.

The selection of a sample population is potentially the greatest source of bias, i.e. whether (or not) the results of a study are representative of the population of interest. The chance of obtaining a

representative sample is highest if some form of random sampling is used²⁷⁴. The target population of this study was normal adults living in an urban environment and working within a clean environment. In order to examine the influences of social stratification and anthropometric determinants on lung function, it was anticipated that three groups would be identified in this population namely a black and white middle class groups and a black lower class group. In order to be able to ascribe an observed difference between these groups to a particular putative determinant (either "race" or social stratification influences) the groups needed to be comparable with respect to all variables other than the putative determinant alone. It will be seen later in the discussion that comparability with respect to social stratification is particularly difficult.

A community-based study with a carefully selected stratified random sample would undoubtedly have offered the best chance of success. This was not possible because:

1. Criteria for social stratification in South Africa are lacking. In addition a vast difference exists in the horizontal development in communities of different "races" (defined by skin colour).
2. Access to black residential areas (townships) was not easy in the prevailing political climate in South Africa. The identification of a group of middle class blacks was also further complicated by:
 - (i) the smaller number of blacks occupying middle social stratification positions,
 - (ii) the great discrepancy between social stratification indicators as a result of the Group Areas Act of 1972²⁶⁰, which ensures that blacks live in inferior areas with respect to both environment and housing, irrespective of their income.

The decision to study the male employees of the First National Bank has already been defended in the methods section. Although it is not possible to compare the Bank's population with the general population due to the lack of census information, it is felt that (for the reasons outlined in methods

Section 1) the Bank's employees are in fact likely to be representative of the healthy section of the general population, yet at the same time avoiding the "healthy worker effect"⁸⁹.

The precision of the results is also likely to be further improved by the large sample size of the original study population. The relatively large random variation in lung functions requires a large sample size in order to allow meaningful statistical analysis of group differences.

The inclusion of a small group of black males from another company (South African Breweries) requires examination. The haphazard inclusion of such a sub-group may detract from the study design by introducing unknown biasing factors. Of concern is the potential occupational hazards that employees of the breweries may be exposed to. The inclusion of these individuals was the result of the Bank management's initiative to replace the group of men who were prevented from participating by their section head during the survey. This latter group of men was the only group of "high" income black Bank employees who did not participate in the survey. Following a request from the Bank, the Breweries made available their black employees working in junior or senior administrative roles and earning in excess of R10,000 per annum. Their office is not located adjacent to a brewery and is situated in the Johannesburg area. All the men were employed in clerical roles similar to the equivalent earners in the Bank and had no contact, past or present, with a brewery. The technologist and radiographer were not aware of their inclusion so as to ensure that their treatment was identical to those of the Bank's staff. Thus it is felt that the inclusion of this group does not in fact introduce a source of error into the survey and was in fact justified.

It is felt the participation rates in all aspects of the study were excellent. It is known that many of the non-participants were in fact smokers and would have been excluded from the analysis group, as will be discussed later in this chapter. It is not possible to compare the response rate with that of other studies because this data is not usually stated in publications.

Measurement bias and random measurement errors (lack of precision) are the second most important sources of potential measurement variation in this investigation. Measurement variation refers to both observer and instrument variation. The term instrument includes physical measuring devices (including the Autolink and Vitalograph, radiometer, thermometers and barometer), and the questionnaire and interview schedules. In the following paragraphs the methodology will be examined with particular reference to the potential sources of measurement variation.

2. Sociological indicators and stratification

The complexity of the question of social stratification has been discussed in Chapters 4 and 5. Since no accurate evaluation of social stratification or its indicators was available for South Africa, indicators of social stratification had to be identified. In this study social stratification was used in its broadest sense as an approach to stratify the study population in terms of certain common characteristics and attributes that separate one group from another. Indicators may be the basis of a social stratification classification themselves, or the consequences of such a stratification. Most attempts at classifying social strata have utilized socio-economic approaches which have attempted to grade populations into several occupation or income groups.

For the purposes of this study, social stratification indicators were used. Thus, the population was divided into two strata demarcated by an indicator which was likely to imply a different set of circumstances sufficient to have profound effects on the two groups so identified. This approach clearly has both strength and weakness. The major weakness is the degree of generalization that occurs in the grouping of large numbers of people into one of two groups. The strength of the approach is that, although there is unlikely to be major differences between one or two levels in a class socio-economic classification, such as that of Simkins²⁵⁰, profound differences exist between the top end and the bottom end of such a classification. Thus, for example, the socio-economic classification based on job categories, was divided into a high group and a low group according to whether people were manual or

non-manual workers. This approach was adopted for each of the presumptive indicators identified prior to the measurement of analysis.

In order to stratify our population, indicators were identified prospectively, i.e. before any statistical analysis was performed to evaluate their validity. This was felt important in order to prevent the error of fortuitous relationships being identified and over emphasis being placed on them as indicators. The prospective identification of indicators was based on the adoption of certain indicators that were used in previous publications. It was decided to adopt the terminology "social stratification". In this scheme, indicators such as "place of birth" (an indicator of environment) and "race" may be viewed indicators of social stratification in terms of access to resources and benefits usually attributed to the more classically utilized "socio-economic" indicators.

It became apparent during the survey that certain indicators were inappropriately defined in the questionnaire, the most important of which was the question relating to home ownership of families during our population's childhood. The majority of blacks answered positively to this question but, in fact, they were referring to a totally different housing structure to that which was being sought by the question. Home ownership has been used as a way of stratifying societies but one is usually referring to the possession of brick and mortar structures rather than the kraals.

Thus the indicators nominated before analysis as being important markers of social stratification were:

1. skin colour;
2. place of birth;
3. father's occupation;
4. school education;
5. sibling death;
6. sibling number;
7. house type;

-
8. current income;
 9. job category, and
 10. home ownership.
 11. ADEC.
 12. home fuel.

It has been recommended by certain investigators²²⁸ that complex indicators made up of several individual indicators may offer a more accurate assessment of social stratification. Although other investigators²³⁰ have shown that this may not necessarily be true, and that in fact some sensitivity is lost by the compilation of composite indicators, composite indicators were proposed including the adult socio-economic indicator (ADEC). It was felt that composite indicators were more likely to reflect an individual's social stratification position than single indicators. It was decided, however, that in the investigation of the determinants of lung function, only those indicators which were shown to have high agreement with the various other indicators, as determined by Kappa interrater analyses, would be included in further analysis.

The above approach may be regarded as a potential defect in the study. The seemingly arbitrary nature in which indicators were identified and the criteria that were used within each indicator to divide the population, may be criticised. However, as has already been stated, the above indicators had all been used in previous sociological studies and had been found to be related to other health parameters in studies examining the relationship between social class and health. Secondly, the categories that each indicator was divided into was based on accepted sociological theory and in most cases represented either (a) the midpoint of an accepted sociological classification or (b) the likely consequence of belonging to either the lower or upper sociological group. Examples of the former (a) is the division of father's occupation into two groups (manual and non-manual), school education level attained (standards nine or ten (upper) and standards eight and below (lower)), house type (brick and mortar (upper) vs natural elements (kraal) (lower)), current income (\geq R10,000 (high)) vs < R10,000 (low),

current occupation into manual (cleaners, catering, security guards) (low) vs junior and senior administration (non-manual) (high) and home ownership (privately owned (high) and rented (low)). Examples of the latter approach (b) include the presence of a sibling mortality (low), 4 or more children within a family, presence of noxious household fuels (low), number of dependants greater than 4 (low). The same approach was taken with respect to the other two major indications of stratification, namely race group and place of birth; black was felt to be likely to be associated with a low level in a social stratification, as was being born in a rural area in South Africa. This novel approach was necessary because of the lack of the sociological information on social stratification that we required for our investigation of the determinants of lung function.

The indicators and their categories that we intended to use in the analysis were based on reasonably well validated sociological theory, their validity was explored internally, using data obtained in the present study. The validity of these assumptions could not be directly tested, although a measure of their validity can be demonstrated. The methods used and the results obtained are outlined in the relevant sections (see Chapters 7 and 8). There is good support for the use of a test to emphasize the need to exclude chance expected agreement. It is important, however, to understand that uncertainty does exist as to how to incorporate the correction for chance into the measurement of agreement. The kappa statistic²⁸¹ was first proposed by Cohen (1960). The variants of kappa have been proposed by Scott (1953) and by Maxwell and Pilner (1968). Landers and Koch have characterized different ranges of values for kappa with respect to the degree of agreement they suggest. As has already been described (see Methods) values > 0.75 may be taken to represent excellent agreement beyond chance, values between 0.4 and 0.75 good agreement beyond chance. For the best interpretation of indicators using kappa analysis, a gold standard indicator (i.e. known to be the "best indicator") offers the best results. There is however ample precedent for the use of kappa, despite the absence of such a gold standard²⁸³.

The identification of father's occupation and school education as two of the best indicators of childhood socio-economic status, using the above technique, is reassuring as both these parameters have been

found valid in previous sociological studies, so offering a form of external validation to the methodology. Birth into a rural area was also shown to be strongly related to the lower categories of most of the other indicators, but not father's occupation. This was not surprising in the light of its anticipated importance because of the political structure of South Africa which enforced black families to remain in rural areas, these areas are known to have inferior resources as compared to the urban areas in South Africa. The poor relationship between place of birth with father's occupation may also be explained in the political structure of South Africa, which previously encouraged a system of migrant labour, whereby men were encouraged to work in the urban areas while their families were forced to remain in rural areas. Similar effects may result from the availability of relatively few non-manual jobs open to blacks as opposed to an abundance of lower paid manual jobs. The powerful effect of stratification based on skin colour (polarisation) is well demonstrated in this investigation. The highest Kappa associations for all indicators are demonstrated with the race indicator. The data arising from the present study would thus suggest that "race" is best indicator of social class in South Africa.

Amongst the adult indicators, current income, job occupation, number of dependants, home ownership and the composite indicator ADEC, as well as skin colour were all found to be good indicators of social stratification. In general, interrater analysis of adult indicators, other than skin colour, demonstrated higher kappa values than indicators of childhood social stratification. This is most likely to be the result of the greater accuracy in obtaining information of current status than that obtained from questions requiring recall of childhood events.

The comparison of childhood and adult social stratification demonstrates that the best relationship is demonstrated between the childhood indicators school education, place of birth, father's occupation, skin colour and all the presumptive adult indicators. It would appear that highest school education obtained and place of birth are the best childhood indicators of ultimate adult stratification. The other childhood indicators relating to sibling number and death are not related in any way to either childhood or adult socio-economic indicators. The indicator "sibling death" is, of course, very arbitrary as it does

not reflect a mortality rate, but merely the presence of the sibling's death. In retrospect, it was likely to have been insensitive and this was well demonstrated by the Kappa test. Sibling number, likewise, is not related to any of the other socio-economic indicators; nor to place of residence of families, but is related to skin colour. The indicator "house type" also appeared to be related to various childhood indicators; comparison with the indicator place of birth reveals that only individuals growing up in rural areas lived in kraals, so resulting in this indicator being no more than a reflection of the urban/rural split.

Place of birth appears to be a very important indicator of social stratification and is closely related to work, health and educational opportunities available, both in childhood and adulthood. In order to examine the amount of movement between urban and rural areas during childhood two questions were asked, one relating to place of birth and one relating to the place in which the individual spent the majority of their childhood (between 0 and 15 years of age). No significant movement occurred between these two environments. A small group of blacks were born in an urban area but lived with their extended families in the rural environment for part of their childhood. It was felt that their birth to families already residing in an urban area would be the factor with the most powerful influence on their social stratification during both childhood and in particular during adulthood. Place of birth was, therefore, chosen as the best indicator of environment in preference to area in which the majority of childhood was spent.

The stratification of the population into place of birth and the relationship with the other social indicators was interesting. We demonstrated a significant relationship between birth in an urban area (as opposed to rural) with both schooling and house type. Black urban children tended to be more likely to enjoy better housing conditions and obtain a higher level of school education. The assumption that living in brick and mortar houses would reflect higher socio-economic status than living in kraals is, of course, controversial. The accommodation available, in urban areas, to blacks during the 1950s, when the majority of our population were children, was certainly inferior to the brick and mortar houses that whites possessed. Nonetheless, it is likely that there was very little difference demonstrated with any of the

other social stratification indicators between blacks living in impoverished conditions in brick and mortar houses versus those living in kraals. The comparison between urban blacks with urban born whites demonstrates a significant difference for the indicators father's occupation and school education. It may be seen that the presence of a chimney (not present in the majority of kraals) was likely to imply a better housing environment in urban areas. The social indicators of black urban children were inferior to those of white urban children but there did appear to be some distinction between the black urban and black rural groups.

It is interesting that when the population was stratified using school education and father's occupation, a significant difference was demonstrated between the white high group and the black high group. A small difference was also demonstrated between the black high and the black low group (low and high referring to the categories with whichever indicator was used). The same was true for adult indicators. This offered support for the fact that although a black middle class had been identified in terms of one indicator, i.e. income group, there was in fact a great difference between the white middle class and the black middle class (termed "black high" and "high white") group.

The main conclusions of the social stratification study are the following, based on Kappa interrator analysis:

1. The black group as a whole occupies an inferior level of social stratification compared to the white group.
2. Within the black group, however, two levels of stratification could be identified, suggesting the early emergence of a "better off" class.
3. Other than skin colour, the best indicators of social stratification include place of birth, school education, father's occupation, current income and ADSTAT.
4. Race, as defined by skin colour, is the best social indicator.

3. Lung function survey

The choice of a cross-sectional study is in keeping with most epidemiologic studies from which normal prediction equations have been derived and the determinants of lung functions investigated. Longitudinal studies, in which the same individuals are examined on more than one occasion over the course of years or throughout their lives, provide valuable information on the development and progression of normal lung function and the effects of adverse influences such as occupational exposure, smoking and other factors. Longitudinal studies are, however, extremely difficult to execute because of difficulties such as maintaining a large number of the original subjects under similar conditions and available for repeated observation, keeping the methods uniform and the time period required. Theoretically the strongest study design to investigate the effects of socio-environmental factors (and, indeed, any other possible determinants) on lung function would have been a longitudinal study commencing at infancy and continuing beyond early adulthood.

A community-based study in which social stratification was easily documented and the demographic features of the population remained relatively stable throughout the study period would have been preferable. In the light of the findings of the feasibility study (see Chapter 6) the decision was made to embark on a cross-sectional work based study.

The choice of an adult population, as opposed to children, requires reflection. It is generally accepted that socio-environmental influences on lung function are the result of adverse effects on the growing lung, primarily during childhood^{100,101}. It would therefore appear logical that an investigation into these effects should be done studying children. Indeed, several studies on children have suggested "race" differences to be present. Therefore, if these differences were in fact a consequence of socio-environmental factors, a study examining this aspect should prove fruitful. Several problems, however, made such a study logistically unrealistic in South Africa; these were outlined in Section 6.3.1, page 98.

In addition to these logistic problems, the following theoretical difficulties were considered:

1. Lung functions are related in a curve-linear relationship to age⁶⁰. Great variability has been demonstrated between different studies addressing this issue. It would therefore be difficult to interpret differences between different groups of the same age.
2. Growth rates have been shown to be slower for blacks²¹¹ (probably due to nutritional factors relating to their position in lower social stratification groups). Height and weight in children and adolescents change considerably over time and so would interfere with group comparison studies.

It has also been well demonstrated that childhood respiratory illness is related to abnormal lung functions in adulthood in cross-sectional studies done in adulthood with retrospective symptom questioning¹⁰¹. These considerations lend support to our choice of a cross-sectional survey of adults as a means of investigating the effects of social stratification, race and other determinants of normal lung function.

To what extent can the results of this study be generalized? This question, in turn, begs the question: How representative are First National Bank male employees of the general healthy population of Johannesburg? As has already been described, a representative population is one that reflects, in the groups studied, the same distribution of social stratification, symptoms, specific disease states, smoking habits and environmental exposures in the overall community. In the absence of any reliable census data, particularly regarding the black population, in the Johannesburg area, it is impossible to determine how representative our sample was.

The large number of healthy black subjects (including lifelong never smokers) living and working in clean environments in this survey gives our data greater strength than most of the previously published surveys which have investigated the influence of race^{61,63,117,195,188,189,190,191,192,193,194}. The distribution of smoking habits of our study population compares favourably with other studies which have examined different racial smoking habits in South Africa²⁸⁴. Our study population worked in a

"clean environment" and was not exposed to any environmental hazards other than the environmental pollution experienced by people living within Johannesburg. This would tend to affect the group comparison aspect of the study, but not the representativeness of the population studied.

The characteristics of the study population have been dealt with earlier in this chapter. The characteristics of the "normal" sub-population (on which analysis was performed) were in every way similar to the characteristics of the total study population. This was an important strength of the study as, in some published surveys, the "normal" subjects that remained after the exclusion of subjects with symptoms and specific disease states do not reflect the demographic characteristics of the general population (see Chapters 1-3). The only significant difference between these groups was the younger mean age of the "normal" group. The average difference in age was 3 years, similar in both racial groups. The age spread was however almost identical, although obviously slightly skewed towards the younger age group in the "normal" group. The majority of subjects were still to be found within the 30-45 year old age group, which was the group of greatest interest. This age group represents young adult men whose lung maturity is most likely to have reached a peak, without age-related loss of volume. The ideal age group for a lung function study is one that spans the age group 25-65 years of age. Of the 208 men included in this healthy group 196 (85%) fell within this age group, with an equal distribution between the race groups. The similarity in age profiles between the two race groups was a strong aspect of this project because comparisons could be made without major adjustment for age-induced effects. In this regard, one area of concern remains, relating to the possible difference in maturation age between different socio-economic strata, and this will be addressed in the group comparison discussion. Several authors who have published predicted values for blacks have based their calculations on surveys in which the black group tended to be in the young adult group 20-30 years of age (see Chapters 1-3). Thus, their lungs were clearly not yet mature; in addition discrepancies existed between the different race groups in terms of their age distribution.

4. Definition of Healthy Study Population

Following Hutchinson's⁷ investigation entitled "On capacity of the lungs and on respiratory function with a view of establishing a precise and easy method of detecting disease by spirometer" in 1846, it was recognized that spirometric measurements can best be interpreted by comparing them to values derived from a "normal" population. In order to investigate the effects of e.g. environmental hazards on lung function, it is also essential that a "normal" (control) population be ideally chosen, so that the cause under investigation is the only variable which is not common to both populations. For both of these reasons the definition of a "normal population" is a particularly important consideration. A common approach is to exclude "abnormal subjects" from the study population. It is in the definition of what constitutes an "abnormal subject" that many surveys limit their usefulness. An important aspect of our definition is that the pulmonary function test results were not included in the definition (i.e. circular reasoning was avoided). It was decided prior to the survey that all individuals suffering from any cardiorespiratory disease, deformity or who had symptom complexes suggestive of cardiorespiratory disease or who previously worked in occupations known potentially to have adverse respiratory effect and who were either current or previous smokers should be defined as "abnormal". The presence or absence of disease was to be assessed using the American Thoracic Society's^{46,51} recommended questionnaire and a chest radiograph.

Different investigators have defined "normal" subjects differently. In most surveys the precise method by which abnormality was assessed is not clear, even if the broad categories of exclusion are stated. An oft found example being the statement that only non-smokers were studied, although whether this includes previous smokers in the definition is not stated. The use of questionnaire and radiograph is believed to be a sufficient screen for normality⁴⁶. The only aspect of the respiratory screening assessment excluded from this survey was the use of a physical examination in addition to the two above. The sensitivity of the cardiorespiratory physical examination has been demonstrated to be lower than the use of an extensive respiratory questionnaire and radiograph⁴⁶. The radiographic survey has been said to offer little added sensitivity above that of an extensive questionnaire in screening programmes⁴⁶. However, the high

prevalence of tuberculosis amongst the black (low socio-economic group) population in South Africa was felt to necessitate a high quality radiographic survey as part of the screening process. The criteria that were used to define abnormality in both the questionnaire and radiographic examination were described in the methods chapter. It will be evident that the criteria for exclusion were extremely strict, e.g. the exclusion of all who admitted to either a cough or phlegm production on three or more occasions a day for more than four days a week for one year or more. This definition is stricter than the ATS or BMRC definitions for chronic bronchitis. The rationale for adoption of the more strict criteria was to ensure that only truly healthy individuals were included in the final analysis. As a possible consequence of this strict selection process, it may be argued that the results of this investigation are not representative of the general population. It is of interest that the frequency of reported symptoms was higher for whites compared with blacks. There are possible explanations for this finding: Blacks who live and work in Johannesburg may represent a super healthy subgroup who have survived against the odds. Alternately, the response rates may be influenced by the fact that blacks report a lower incidence of symptoms for several reasons, including a poorer understanding of the questions or fear of victimisation by management or because of a different level of perception of relatively minor symptoms. It is therefore possible that the black healthy group identified in this study are actually less "healthy" than the white healthy group and that this difference accounts for group comparison differences demonstrated. In order to investigate the determinants of lung function it is essential that confounding factors such as incidental diseases be eliminated. It is also felt that the representativeness of our study population was still reflected in the "normal" sub-groups.

5. Radiographic Survey

The radiographic survey was a cross-sectional study, designed to detect the presence of active disease (e.g. tuberculosis, cardiac failure, tumour) and previous pathology. The goal of the survey was to identify abnormal radiographs indicative of pulmonary, cardiac or thoracic cage abnormalities which were likely to interfere with lung function. The inclusion of a radiographic examination may result in several sources of error affecting the results of the survey. The major problems involve the quality of the radiographs and their interpretation. These will be dealt with in the following paragraphs.

Although no formal internal quality check was performed, the radiographs were inspected on a regular basis during the survey by an experienced radiologist and chest physician, both of whom commented on the excellent quality of the radiographs. The major defect noted by these inspections was the number of radiographs in whom a maximal inspiration had not been achieved. This problem had already been identified by the author and radiographers, but despite a concerted effort it could not be rectified. Failure to understand the technique required was thought to have been minimised by the fluency of the radiographer in most of the home languages of our subjects. The majority of these films were passed as being normal. Radiographs were repeated where a clinical assessment in the interest of the subject could not be made due to a poor quality film.

The methodology for the interpretation of radiographs in epidemiological surveys, other than for pneumoconiosis, has not been standardized. The radiographic criteria for the diagnosis of emphysema in particular remain to be defined and standardized. In order to ensure that the radiographs were examined in a consistent manner and that reproducibility of findings could be assured, a standardized format was devised prior to the evaluation of the radiographs. This classification is outlined in Methods, and is based on accepted clinical criteria²⁸⁵. Films with parenchymal calcific shadows were handled as follows: Fine calcific speckling (defined as calcific foci smaller than 2mm diameter distributed within the lung parenchyma) was regarded as unlikely to be indicative of generalised disease. The most likely cause of such radiographic changes is previous chicken pox pneumonitis and studies on these people

have shown no abnormality with regard to mechanical lung function²⁸⁶; thus, this group of subjects were included in the analysis as normal subjects. On the other hand, an isolated calcific focus for example, in the posterior segment of the upper lobe, or anywhere else, was assumed to reflect previous tuberculosis which may have caused more widespread disease; such subjects were excluded from the "normal" group.

Potentially, the most serious defect in the radiographic survey was the decision that those subjects whose radiographs were technically imperfect could be included in the normal group. The most frequent reason (96%) for radiographs to be judged as technically imperfect was because the anterior aspect of the sixth rib was not seen to traverse the diaphragm on the postero-anterior view. The remaining 4% were similarly classified either because of poor positioning (resulting in either a rotated film or portion of the thorax being "cut off"), or over-exposure of the film. These latter individuals, as well as those who did not undergo radiographic examination (excluding those who were able to present a normal radiograph) were excluded from the analysis. The X-ray plate readers were asked to assess such films as being (a) normal despite the inadequacy of the inspiration (2/1), (b) any categorical statement was impossible (2/2), or (c) that other pathology was suspected (2/3-8). Only the first group was included in the analysis. In the light of these precautions, it seems unlikely (although possible) that a significant number of subjects with significant pathology might have been included in the analysis.

Inter-observer variation in radiograph readings was not formally assessed. It would have been preferable to institute a technique such as the receiver-operating characteristic (ROC²⁸⁷) curve or an interrater (kappa²⁸¹) test to assess the ability of the radiograph interpreters to evaluate radiographs in terms of both accuracy and consistency. In any event, our aim was to exclude all subjects with abnormal films and rejection by any one of the readers led to elimination of the subject from analysis.

An important aspect of the radiograph survey was the observation that there was an increased prevalence of abnormalities in the lower social stratification group (e.g. "blacks", rural born). It is in this

group that the lowest symptom rate was reported and thus the additional knowledge gained from the radiograph examination was valuable in the assessment of "normality". Although only relatively few abnormalities were identified, it justifies the use of the additional screening modality. Perhaps the most important aspect of the radiographic survey is the ability to be certain that significant pathology had not been missed.

6. Survey Questionnaire and Data Gathering Techniques

The questionnaire served as an important "instrument" in the survey. The potential for measurement variation as a result of defects in the questionnaire is perhaps the major potential source of bias in the methodology of this investigation. The two main goals of the questionnaire were to

1. identify normal subjects, and
2. determine social stratification indicators.

These two aspects are of course central to the successful outcome of this investigation. The results of the questionnaire were generally highly reproducible, as assessed by re-interviews carried out by the author (described in Methods Section). Nevertheless certain difficulties may have given rise to systematic bias errors and these will be examined in the following paragraphs.

The section of the questionnaire used to gather identification data, including age, area of residence, marital status and home language was adopted from the ATS⁴⁶ recommended questionnaire. The age of participants was ascertained in this section both directly by inquiring about the age of the subject at his birthday and also his date of birth. In addition, ages were also obtained from the personnel records of the bank. In a few cases ages varied between these data sources. Where the ages differed by five or more years the data was discarded and the subject excluded from the analysis. The discrepancy in ages was found almost exclusively within the black group. In the case of lung function determinations, inaccurate ages are likely to adversely bias the outcome of both regression and covariance analysis techniques. It was for this reason that individuals whose ages differed between any of the three sources

were excluded. It is possible that inaccurate ages may be an important source of error in other studies investigating lung functions in blacks.

The section of the questionnaire used to evaluate the health status (with particular reference to cardiorespiratory health) was adopted from the ATS⁴⁶ recommended questionnaire for lung function surveys. These questions have all been evaluated in major epidemiological surveys and their validity has been accepted by the American Thoracic Society. These questions were also adopted to conform with the standardization recommendations of the American Thoracic Society to allow comparison of the lung function measurements in this survey with those of other studies.

The sections of the questionnaire directed at establishing childhood and adulthood social stratification status do not have a similar established standardized and accepted status. For this reason extensive measures were undertaken to establish the validity of the questions that were used and therefore the data that was obtained.

A possible defect with the questionnaire was its length. Many subjects felt under tremendous time pressure and the sight of the lengthy questionnaire, in certain circumstances, resulted in a negative rapport being struck between interviewer and interviewee and possibly rapid, thoughtless answering in order to reach the end. The length of the questionnaire was mainly the result of the numerous questions included in an attempt to establish social stratification. Some questions were included despite the fact that the likelihood of their being of any value was already in doubt during protocol development. The major reason for certain questions falling into rapid disrepute was either the fact that the question required information that clearly could not be relied upon (e.g. whether an individual was breastfed or vaccinated) or because the question was not specific enough (e.g. the question enquiring as to parental home ownership during childhood which was aimed at identifying people whose parents owned brick and mortar houses and not kraals) or, finally, because the question was vague in both its structure and its purpose (e.g. was your father away from home for more than six months of each year). Many of the

above considerations were anticipated prior to the survey, but because of the lack of thoroughly validated social stratification data for South Africa, it was felt that these questions should be included.

The single biggest defect in the structure and composition of the questionnaire relates to the problem of cultural and language differences. Cultural differences resulted in problems with semantics. This was particularly evident in the respiratory symptoms section. Another problem was the need to ensure that the questions and statements were "value free". The language of the questionnaire itself and that in which the interview is conducted, should ideally be the same as that of the interviewee. An excellent example of an effort to eliminate this source may be found in an Italian study, where the ATS questionnaire was adopted and then translated into the local dialect and performed by interviewers of the same population¹²⁴. The difficulties encountered when the languages of the questionnaire and interviewer are different to that of the interviewee have been addressed in a recent publication²⁸⁸. In anticipation of these problems it was planned to have (1) two interviewers belonging to each of the race groups studied, (2) to have a translator proficient in all the languages likely to be encountered and (3) a vernacular translation of the questionnaire. The aim of the vernacular translations was to ensure that translations were standardized and the questionnaire would be administered in a manner identical to the original English version. Two major problems were however encountered.

Firstly, the black interviewer withdrew from the survey and it was impossible to recruit another interviewer of the same language group. The replacement interviewer was fortunately able to speak the most commonly encountered language, Zulu. Secondly, the vernacular translation was found to be of value only in translations involving members of the black group who had completed a standard nine or ten education and who were unsure of the precise meaning of an occasional question. It was not found to be of any practical value in assisting with interviews involving less well educated black subjects. This was apparently due to a significant difference between academic Zulu and Sotho (into which the questionnaire had been translated) and the practical form of the language spoken by less well educated individuals. It was found that the best way to ensure standardization of the interview technique, in the

circumstances, was to use the translator. The question would be asked by a trained interviewer in the normal fashion (being read from the questionnaire by the interviewer), but translated by a translator present at the interview. The problem with this approach was that interviews took on average 50% longer, but when an attempt was made to use the translator without the trained interviewers, strict adherence to the interview technique was lost. There is very little documentation available, but it is unlikely that any of the other surveys have addressed this particular aspect with the same attention to detail. Thus, although it is recognized that the quality of data obtained in the interview possibly suffered, some progress has been made towards developing a technique to minimize inter-observer variation.

The questionnaires were administered by unbiased lay people. It is controversial as to whether health personnel or professionally unbiased lay people are better at eliciting people's perceived health status²⁸⁹. It is, however, generally accepted today that trained lay people are less likely to introduce an observational bias. In order to minimize the potential sources of variation that may result from faulty interview technique, the ATS⁴⁶ recommendations regarding both training and interview technique were strictly adhered to.

The use of the tape recording ensured the interview were both standardized and at all times optimal. The use of recordings also greatly improved the quality of data, by allowing assessments of the understanding of the interviewees of the individual questions. Several problems were identified by reviewing both the recorded interviews and repeat interviews. The most important problems encountered in this respect included:

1. An obligation to answer questions despite poor recall (this was particularly important with respect to childhood data questions) and as a result a guess or any reasonable sounding response may have been recorded.
2. Subjects at times consciously have given responses according to their interpretation of the answer the interviewer wanted or in order to hide the truth (e.g. the denial of respiratory symptoms for fear of victimization) or

3. answers elicited on occasion have been influenced by other subjects present at the survey clinic at the time of the interview rather than based on the individual's own experience.

The ability to assess the standardization of translation used by the translator was an important advantage including tape recordings of the interviews. Audible comparisons of the two translated interviews demonstrated the use of similar key words and, more importantly, the length of translation and so assisted in ensuring adherence to a standardized questionnaire. Although it is accepted that translated interviews were likely to be more open to variation than intended, it is felt that the use of recordings minimized this potential source of error. The translator was noted to have a tendency to decide on final answers for his interviewees and on occasions to combine two or more questions into one translation. These techniques were discouraged and again the ability to review the interview from the tape recording was invaluable in minimising the practice.

Intra-interviewer variation is a well documented source of error in epidemiological studies²⁸². Interviewers may vary in the way in which they administer a questionnaire, so varying the standard of data obtained. The electronic transcripts of the entire interview in some cases or, samples of each interview, were evaluated by the author daily and by the research sister when time permitted. In this way problems in handling situations which had not been anticipated in the training programme could be identified and the interviewer technique corrected. Also the tendency to either rush interviews or change wordings or explain questions was greatly discouraged by the knowledge that these reviews would take place. On a weekly basis interviewers heard examples of both good technique and weak technique in an attempt to standardize the interview technique. These sessions, which were held confidentially between the investigator and the particular interviewer, were of great benefit. Certain questions did require explanation (e.g. the definition of urban and rural, the meaning of medical terms such as asthma, emphysema, etc.) and a list of these explanations which had been drawn up prior to the study were the only explanations allowed during the survey. Tape recordings again ensured adherence to this rule.

It may be concluded therefore that the inclusion of electronic recordings ensured a high quality of data because of the close monitoring influence, the training advantages and the ability to perform validation checks on a random sample. The interpretation of what constitutes a dusty job gave rise to the greatest difference between cross-check interviews and recorded interviews. In the cross-check interviews subjects who responded affirmatively to the question but who did so on the basis that they experienced dust in the course of their work at the bank (e.g. filing documents) were coded as negative responses. During the survey interview this interpretation of a dusty job was on several occasions incorrectly recorded and coded as affirmative responses. The otherwise very good comparisons between cross-check interviews and recorded interviews requires explanation. The comparisons were in fact better than one would anticipate for such a survey. This is particularly evident when one examines the responses to the question of age. Within an interview, the age recorded could differ from that calculated from the date of birth and yet in the cross-check interviews the same error recurred. It would be anticipated that these people were unsure of their ages and/or date of birth and that consistency in this error would be unlikely. The most likely explanation for the consistency demonstrated was the fact that the cross-check interviews were all done within the same session, the majority immediately after the survey interview having been performed. In retrospect, it would possibly have been more useful to perform the cross-check interviews following a substantial time interval. This does, of course, detract from the strength of the quality control inferred from the results, but it is likely that the conclusions drawn regarding the good interview technique and low interviewer variation are valid.

7. Lung Function Measurements

The equipment used and testing methodology employed is a crucial aspect of any lung function survey and the potential for measurement variation is great. Perhaps the greatest benefit of the standardization attempts of both the ATS¹⁹⁸ and ITS has been the reduction of much of the variation^{46,51,52}. Unfortunately, the rapid development of computerized systems outstripped the advice given by these two agencies and resulted in new sources of potential measurement error. The most recent ATS (1988) standardization update does however address the issue of computerisation and offer guidelines in this

regard⁵¹. Although this information was not available at the time of this investigation, the automated system and computerized lung function analysis software that were used do in fact comply with these recommendations²⁷⁷. The strict adherence to the above-mentioned recommendations ensured the minimisation of measurement error. In the following paragraph possible sources of variation will be discussed.

During the pilot survey it became apparent that a consistent discrepancy existed between measurements obtained using the two spirometers. The Autolink flow-volume loop measurements for both FVC and FEV₁ were consistently greater than the same measurements obtained from the Vitalograph's spirograms, the mean difference for FVC was 200 mls and FEV₁ 180 mls. For this reason it was decided to perform measurements with both spirometers on all subjects during this survey.

The difference was demonstrated to be consistent throughout the survey, irrespective of the order in which the tests were performed (which was deliberately randomized). The finding was also constantly reproduced during the 10% repeat sample survey. The consistency of these observations would appear to exclude the possibility that subject variation (e.g. a training effect) was the cause for the differences. A systematic error (or instrument bias) is thought to be the most likely basis for these differences. It is, however, important to realise that both instruments constantly stood up to repeated biological and mechanical calibration checks. It is thus unlikely that faulty calibration or technique was the cause of the instrument variation. The Autolink's computational programme was initially suspected as a potential source of this variation, but stringent calibration tests, including the use of flow generator curves (adhering to the ATS criteria for computational software accuracy) excluded this possibility. It is felt that the most likely basis for the differences demonstrated is the enhanced functioning of the more modern apparatus. This is presumably due to the lower resistance of the rolling seal spirometer and the highly sensitive potentiometer's ability to measure flow. Regression and covariance analysis was performed on both sets of spirometric measurements. The R² and CP values obtained did differ slightly between the Autolink and Vitalograph studies. Reasons for these discrepancies include the slightly different characteristics of the subjects, the different number of subjects and the different ranges of the predictor

variables, as well as the influence of the different apparatus. The consistency of differences did not significantly affect the outcome of the statistical analysis performed on the different sets of results. The regression analysis performed on the Autolink measurements formed the basis for the prediction equations generated and this should be considered in the interpretation of the results.

Observer and subject variation were limited by adhering to standard acceptability and reproducibility criteria.

It has been suggested that no greater than 8^{51,290} attempts at obtaining functions that meet ATS requirements should be necessary. It was decided to adhere to this recommendation, but the technologist was given leeway to perform up to 10 tests if she felt that this was required. It is worth noting that on several occasions she was able to demonstrate that 6-8 attempts were insufficient, but that following 10 attempts, excellent data could be obtained.

The best FEV₁ and FVC were selected from any of the three traces meeting the ATS requirements for reproducibility and acceptability. Although the latest ATS (1988)⁵¹ recommendations suggest that measurements may be included in the analysis when only 2 acceptable traces are obtained, we included measurements in the analysis only if 3 traces were obtained. The stringent adherence to this protocol is possibly one of the explanation for the high rejection rates demonstrated.

A greater rejection rate for Autolink than for Vitalograph functions might be expected due to the more difficult manoeuvre required to perform a flow-volume loop. In the lower social stratification groups the rejection rate for the Vitalograph was in fact higher. To perform the Vitalograph manoeuvre, the subject must inhale maximally from room air and then insert the mouthpiece, whereas in the performance of the flow volume loop the subject is attached to the apparatus throughout the procedure. This difference in technique may explain the higher rejection rate for Vitalograph trace. The test sequence was randomized in order to ensure that a training effect did not result in the discrepancies demonstrated.

The decision to duplicate the measurements on two different spirometers and to randomize the order in which these tests were performed resulted in the greater than expected number of omitted cases. Although only 2 subject performed neither test, 22%, and 18% respectively did not perform either Autolink or Vitalograph. The number of subjects with lung function data missing in the normal sub-group may have detracted from the representativeness of the study. It was decided that although the difference in measurements between the two spirometers was consistent, it would not be justified to combine the results. The use of different pieces of apparatus have been shown to affect measurements significantly. Although other surveys have analysed data obtained with more than one piece of equipment, it was felt that the combination of results may interfere with the regression and covariance analysis. It is felt, however, that the reasons outlined above and the high testing rates achieved for both spirometers justified this decision and did not introduce a significant error in the results.

8. Findings

The major findings of this investigation were the following observations:

1. Lung function measurements (spirometry and $TLCO_{SB}$) are influenced by anthropometric determinants; the combination of age together with sitting height and the ratio sitting height/standing height are the most important.
2. Spirometric measurements are also influenced by social stratification; at present "race", as defined by skin colour, is the most important indicator of social stratification. Other social stratification indicators, including father's occupation and current income, however, influence spirometric measurements to a similar extent.
3. Sufficient evidence has been demonstrated to question the acceptance of a genetic factor as the basis for these race differences in spirometric function; it is probable that these differences, in fact, reflect the effects of sociological pressures and not genetics.

This section will examine the extent to which these conclusions may be substantiated. The strict adherence to accepted methodology and the demonstration that the results were internally consistent,

plausible and valid already offer credibility to the conclusions. Nevertheless, further support for these findings will be discussed in the following paragraphs.

1. Anthropometric determinants of lung function

The conclusions that anthropometric measurements and age are important determinants of lung function, based on the data obtained in this study, are inescapable. There is no need to consider alternate explanations for this conclusion as this finding is consistent with those of other investigators.

The findings of this survey suggest, however, that both spirometric and transfer test (TLCO_{SB}) measurements are better related to sitting height and the ratio sitting height/standing height than standing height. In the case of FVC and FEV₁ measurements, both the R² and Mallows CP are improved significantly when the regression analysis includes the former anthropometric measurements. The improved regression equation derived by the inclusion of both sitting height and the sitting height/standing height ratio is also demonstrated with transfer test measurements. Analysis of covariance examining transfer test differences between different groups also demonstrate that the correction of groups (as part of the covariance analysis technique) by use of these two parameters, rather than standing height, reduces group differences.

It has been suggested that the difference in spirometric function in relation to height that have previously been demonstrated for different race groups may be explained by the greater proportion of total height contributed by the lower extremities in black groups. The results of this investigation however, does not support this contention in the "race" groups under study. The sitting height/standing height ratios for both blacks and whites were demonstrated to be the same (0.51); this figure agrees with that found by Stinson et al⁷⁷. The inclusion of the ratio in the regression analysis consistently improves both the R² and CP values obtained. This ability to improve the prediction of the dependent variable strongly suggests that sitting height/standing height ratio is a better indicator of thoracic size, as is sitting height, than the traditionally accepted standing height measurement.

Sitting height has previously been demonstrated to be a good predictor of spirometric function⁶⁹. A recent publication has again suggested that sitting height should be used rather than standing height, but this paper was based on small number of subjects²⁹¹. Standing height has been preferred because it is an easier and more reproducible measurement. This investigation would probably have reached a similar conclusion had it not been for the inclusion of the ratio, in addition to both height measurements (sitting and standing) in the regression analysis. It is important however to note that it is the combination of both sitting height and the ratio that improves the ability to predict the dependent variable over the use of standing height alone.

This is particularly true for the single breath gas transfer test measurement. The inclusion of sitting height and height ratio as independent variables for this measurement results in an excellent prediction equation. In the group comparison studies (e.g. between blacks and whites) significant differences between transfer tests were demonstrated when the analysis technique only takes into account standing height. If, however, sitting height and height ratios are substituted for standing height, no significant differences are demonstrated between groups. Although it is generally accepted that race differences do not exist for $TLC_{O_{2B}}$, at least one investigation (that of Rossiter)¹¹⁷ has found blacks to have a 6% lower measurement for $TLC_{O_{2B}}$ than whites. It is, however, possible that Rossiter's findings are due to the fact that sitting height and the sitting/standing height ratio were not used as the anthropometric determinants.

2. The influence of social stratification on lung function

Our data shows that when the population is stratified using the social stratification indicator "race", blacks have lower values for spirometry than whites. This finding is inescapable when the results of this study are examined. The conclusion that these differences are due to inherent genetic differences is, however, seen to be less likely when the results of the regression analysis and social stratification investigation are examined. These apparently contradictory statements are in fact the most important conclusion of the survey.

1. comparison of our data with other studies on lung function in blacks and whites,
2. results of the regression analysis in which anthropometric and social stratification indicators are examined,
3. results of other covariance analyses examining differences in spirometric functions between different social stratification groups.

Our data shows higher spirometric values for "blacks" and "whites" than other authors (see Tables 2 (i) - (v) and 3 (1) - (v)). Examination of studies into lung function in blacks (see Chapter 3 demonstrates that a wide range exists between predicted normal values. Mengesha and Menkonen¹⁸⁸ predict values for FVC among blacks similar to those predicted by most studies of whites. Several studies predict values for FVC that are almost identical for both groups and demonstrate higher values than other studies have demonstrated for whites.

The area of overlap between predicted normal spirometric values for blacks and whites has often been used to dispute the acceptance of different normal values for different races. It is probable that the larger spirometry values demonstrated in this study is due to the fact that we studied blacks who were urban dwellers working in a clean environment, and lifelong never-smokers. Most of the previously reported studies were performed on industrial workers who, although screened for normality (to varying extents), were at risk from the adverse respiratory environment in which they worked. Other studies in which substantially lower functions for blacks compared to whites were demonstrated were based on small groups of blacks composed of subjects with varying smoking histories and adverse respiratory symptomatology. An alternative explanation for the larger values demonstrated in this study investigation is the possibility that the standard of living and resultant better general health of blacks employed in the banking profession and living in Johannesburg is superior to those of blacks studied in other surveys, thus reducing the effects of environmental pollutants on spirometric values.

Our results also demonstrate smaller differences between the spirometric functions for the two "race" groups. This is an important corroborative finding, casting doubt on inherent race differences. Many proponents of the genetic theory for differences in spirometric values among different races have asserted that there are simple proportional black-white differences "in the region of 13-15%" in spirometric functions^{47,131}. In this study the values for blacks were found to be 11% lower than whites, which is less than that which would be expected by the proponents of proportional differences. The large difference between the findings for black spirometric measurements in this study and those reported in most other studies of blacks, together with the smaller difference demonstrated between the black and white group in this study, do not support the previous assertions of a purely genetic explanation to account for race differences in spirometric function. It is of interest that a recent study in South Africa demonstrated a 19% difference between blacks and whites; the blacks in De Kock's study all worked in dusty jobs within a mine environment⁶. It is therefore not surprising that their functions are considerably lower than those demonstrated in our study. The social stratification position of the blacks in De Kock's study is likely to be lower than that of the "whites" in his study, and both the "black" and "whites" in the current investigation. Professor de Kock argues that anthropometric differences in various tribes differ, and that the tribes in his study may thus have body configurations that differ with resultant differences in lung volumes (personal communication). We contend that when the effects of social stratification and environmental pollutants have been taken into account, a "genetic" explanation for observed differences in spirometry remains an open question.

It has been pointed out that lower volumes for blacks compared with whites is not demonstrated when the ratio FEV_1 to FVC is examined. Investigators have stated that the ratio is in fact higher in blacks, implying that although the lungs are smaller, they are not necessarily less efficient⁶. It was clearly demonstrated in this investigation that this ratio was identical in our two population groups. Most other studies also do not demonstrate these differences between race groups, thus raising doubt that the differences in the ratio observed by the authors quoted above are generalizable.

Nevertheless, the analysis of functions between high and low social stratification groups (whether divided by father's occupation, school education, income, ADEC) demonstrate consistently smaller lung functions for the lower group. It may be argued that such findings, which are clearly evident when one reviews the results, offer support for social stratification rather than race as the cause of the lower functions. This interpretation suffers from the same defects as the argument on which race differences are based. It is quite obvious from this investigation that race and the other social stratification indicators are so closely related as to prohibit attempts to separate the two sets of factors.

It is interesting to observe that when our study population is divided into three social stratification groups representing black middle class, white middle class and black lower class, consistent differences between these groups are noted. In all cases, spirometric functions are significantly higher for the white middle class group, compared with both the black middle and the lower stratification groups. When one examines the results of the social stratification investigation, it is evident that a difference exists when one compares the relative social stratification positions of blacks in relation to whites. Whites clearly occupy a higher social stratification level than blacks. The very small differences demonstrated in lung functions between the two black groups corresponds to the similarly small gradation in social stratification demonstrated within the black population. It is, however, possible that even this marginally improved social stratification position results in an equivalent improvement of lung functions. This conclusion is no more than speculative but, nevertheless, worthy of consideration.

Of particular interest to this investigation was the effect of the social stratification indicator "place of birth" (urban vs rural) on lung function. Amongst other aspects, this indicator is thought to reflect mainly environmental differences during childhood. Interpretation of the covariance analysis of the study groups divided according to this variable is complicated by the fact that the black vs white groups were not comparable with respect to other social stratification indicators. The comparison of urban born blacks with rural born blacks is influenced to a lesser extent by this difficulty. Examination of the results of this analysis demonstrates no significant difference in the spirometric functions of blacks born in these

contrasting environments. It is very likely that this finding is correct, given the large number of urban and rural born blacks in the study. Nevertheless, other explanations for the conclusion need to be considered. It is possible that the group of rural "blacks" represent a highly selected sub-group of rural blacks. Given the high infant mortality rate for rural blacks in Africa, any individual who survives to adulthood and is fit enough to migrate to the city to seek employment may represent two healthier sub-group. The relatively low reporting of symptoms and illness in this investigation for rural blacks compared to other groups may offer support for this contention. Urban born blacks on the other hand, may have been born into relatively poor housing conditions and smoke-polluted environments. In addition, the social stratification position of the urban born black subjects' parents was generally found to be low. It is, therefore, possible that urban born blacks (particularly the current adult generation) were in fact no better off than their rural born counterparts. It is possible that they may even have been worse off with respect to nutrition and environmental pollution. Support for this possibility may be found from studies of urban and rural born populations in Chile²⁹³. Thus, the failure to demonstrate differences in spirometric function between urban and rural born blacks may be the result of multifactorial influences acting on both groups. The comparison of the white urban born and black rural groups, which reveals significantly lower spirometric functions in the latter group, may in fact be a better reflection of the effects of optimal urban versus rural conditions.

If one considers "race" to be, in the context of this study, no more than a sociological class concept, then it follows that spirometric functions differ considerably between rural and urban environments in South Africa. Such differences have been suggested in some studies, although they have been contested in others. (See Chapters 2 and 3). Comparison of our results with these studies is meaningless when one considers the large differences that are likely to exist between the living conditions of traditional rural born blacks in South Africa and the rural farming communities in the United States.

In order to examine the marginal differences demonstrated between black higher and lower stratification groups, the data base was enlarged to include healthy previous smokers. A comparison of this group

with lifelong never-smokers demonstrated no significant difference in spirometric functions. It was anticipated that the increase in group sizes may improve the likelihood of demonstrating significant differences in spirometric functions between these groups. The results obtained were almost identical to the initial analysis of lifelong never-smokers. It was not possible to compare healthy smokers because of the lower spirometric functions demonstrated in many of the groups (when divided by social stratification indicators).

TLC_{05B} does not appear to be influenced by social stratification indicators. Following similar analyses to those performed with spirometric functions, no differences could be demonstrated for gas transfer.

In the preceding paragraphs it has been demonstrated that group comparison techniques to examine the effects of social stratification on lung function is not appropriate, since homogeneous groups with clearly differing SS positions could not be identified. Another technique that may be employed to investigate the determinants of normal lung function is that of multiple linear regression analysis. It has already been demonstrated that the anthropometric and age determinants of spirometric measurements and TLC_{05B} can be examined in this way. The observation of different mean functions for different "race groups" and the apparently more accurate prediction equations that were obtained when regression analysis was performed on the data from separate race groups led to the current acceptance, by many authorities, of different normal values for race groups.

An examination of the results obtained in the regression analysis in this investigation demonstrates that spirometric measurements are inescapably influenced by social stratification indicators. It has been clearly demonstrated that both the multiple correlation coefficient (R^2) and Mallows CP are improved when social stratification indicators, as well as anthropometric and age determinants are included in the regression equation. It is possible to explain (with an $R^2 = 68\%$) the dependent variable (FVC or FEV₁) for the whole population (black and white) by the inclusion of independent variables including [sitting height + height ratio + age + social stratification indicator father's occupation or other social

stratification indicators such as current income or ADEC. The "normal" values predicted by this equation are almost identical to those predicted by the equation [sitting height + sitting height/standing height ratio + age and social stratification indicator race] when one compares the R^2 and CP values obtained, as well as the results of Cooke's distance analysis (see Table 8 (xxxiii) (a-d) and 8 (xxxiv) (a-d)). Although slightly improved prediction is achieved by the use of the social stratification indicator "race" this may be understood by reference to the social social stratification investigation. Social stratification as determined by "race" was demonstrated to be the indicator with the best relationship to other social stratification indicators. This result makes it highly probable that "race" is the most important indicator of social stratification. Support for this conclusion may be found in the sociology literature²⁰⁹, thus it is not surprising to find that the inclusion of the best social stratification indicator in the regression analysis improves the results obtained.

It is worth reflecting again on what is meant by the "best" indicator (see Chapter 4 and Chapter 5 for details). Social stratification indicators attempt to stratify populations into groups who share common access to society's resources and the resultant benefits of this access. The relationship between "race" and social stratification is well accepted in the sociology literature. Inclusion of other social stratification indicators also improves the regression analysis in a similar way. At present this improvement is attributed to inherent genetic differences between race groups. The results of the present investigation suggest that such a conclusion may be simplistic. Since both environmental influences and genetic influences may be linked to "race". It is probable that such a conclusion is also unscientific and incorrect, since convincing evidence (where environmental influences have been eliminated) that purely genetic influences determine the spirometric differences among different races is lacking. Support for this latter contention comes from both this study and other studies²⁰⁵. In this study it has been conclusively demonstrated that race is inextricably bound with social stratification. It may therefore be argued on the basis of the evidence accrued from the present study that the relationship between race (and indeed other social stratification indicators) and spirometric function is a reflection of the

sociological influences (nutrition, health and environmental) on lung development and not due to genetic differences.

The alternative explanation is that the racial effect noted in spirometric values is the result of genetic differences, but that it is also closely related to social stratification. This latter relationship is due to the fact that blacks belong to lower stratification groups as a consequence of both past and present sociological dynamics (e.g. apartheid and colonial rule). This argument would then assert that the influences of other social stratification indicators on lung function are due to the fact that they indirectly represent "race" when included in a regression model. It is not possible, on the basis of the results obtained in this investigation (due to the almost caste like system that separates blacks and whites in South Africa) to refute this explanation. The central issue revolves around the understanding of the concept of "race". If one assumes that race (as defined by skin colour, as is usual in the medical literature) represents homogeneous groups determined by genetic pools, then this alternate hypothesis is easily accepted. However, this assumption ignores the increasing evidence in the scientific literature that the race (as defined by skin colour) is primarily a sociological phenomenon, with little biological content. In addition, a number of studies have demonstrated the relationship between socio-economic factors and health, including lung function. Studies in other biological disciplines have also resulted in the absolute rejection of previously accepted racial differences, once other factors were investigated (see Chapter 4). The conclusions reached in this investigation concerning race and social stratification are therefore supported by experience gained in other biological models.

Regression analysis investigating the anthropometric and social stratification determinants of $TLCO_{SB}$ demonstrated conclusively that anthropometric measurements and age are the most important determinants of this measurement. It was conclusively demonstrated that the combination of sitting height and height ratio are better predictors of single breath than is standing height. $TLCO_{SB}$ is dependent on the area available for gas transfer and this is related directly to thoracic size. The improved prediction obtained by the use of sitting height and sitting height/standing height ratio is likely

to be due to their ability to better reflect thoracic size. Social stratification indicators, including "race", were not demonstrated to influence $TLCOS_B$. These findings are in keeping with the previous publications.

9.4 ASSESSMENT OF THE EXTENT TO WHICH THIS STUDY MET ITS AIMS

The major goal of this investigation was to test the hypothesis that social stratification indicators and environment in childhood play a dominant role in the causation of lower spirometric values previously demonstrated in blacks compared to whites. It was anticipated that a population in which blacks and whites occupy similar social stratification positions could be identified. It was anticipated that group comparison studies would then allow the interaction between race and social stratification to be examined. This goal was extremely optimistic in that it underestimated the complexity of social stratification in South Africa. The knowledge (derived from the pilot studies) that comparable income groups existed in the Bank among the White and Black employees, led to the decision to proceed with the study in the hope that the high income group of Blacks might have enjoyed a privileged childhood comparable to the Whites, but better than the low income Black employees. It was believed that an emergent black middle class had developed to the extent that the survey was feasible. These views had been expressed by leading investigators in this field at the commencement of this investigation. The situation, however, proved to be far more complex. The complexity of the concept of "race", as developed in Chapter 4, was also not initially appreciated.

"Blacks" in South Africa have over recent years begun to occupy more senior positions in the workforce with resulting higher incomes. The effects of pilarisation (which has been demonstrated for blacks elsewhere in the world) are, however, nowhere more obvious than in South Africa as a consequence of the apartheid legislation. With few exceptions blacks live in more polluted environments, in inferior housing and have poorer access to health resources, irrespective of income or occupation. Only marginal gradation may be demonstrated within the black urban community of Johannesburg. The use of any single indicator can not be expected to give an accurate reflection of social stratification.

It was evident during the planning phase of this study that the stratification of Black employees (namely black middle class and black low class) might not be definable. The identification of a population of black men in middle class jobs in the Bank, however, was sufficient motivation to pursue the project. It became apparent that the group comparison analytical approach that had been planned originally might be inadequate to examine the influences of social stratification on lung function and so it was decided to adopt regression analysis as the main analytical technique.

Despite these difficulties the current investigation has been able to achieve much of its primary goal. The social stratification profile of Johannesburg (the most affluent city in South Africa) has been described in three representative groups. The relationship of social stratification and race has been examined and their relationships to lung function explored. It is not possible to separate race and social stratification and this fact has prevented the first aim of the project from being fully realised. Our analyses suggest that social stratification does have a profound influence on lung function, thus, the conclusions reached by previous studies (where large race differences have been demonstrated, but without examining other social stratification indicators) ought to be questioned.

With regard to the two other goals of this project, namely to collect data on lung function in normal South Africans and to develop prediction equations for white and black males on the Witwatersrand to have been fully realized.

NEW HYPOTHESIS AND RECOMMENDATIONS AND SUGGESTIONS FOR FUTURE STUDIES

1. Future Research

The relationship between race and the scientific discipline medicine is an interesting one. Currently the majority of researchers and clinicians accept race as a determinant of various health and illness phenomena, in the same way that they accept other descriptive terms such as age and sex. "Race" is usually defined in the medical world in terms of skin colour, which is the usual method used to classify

patients in clinical and epidemiological trials. It is usual for investigators to examine for race relationships in their findings as part of their preliminary descriptive analysis. If an association is demonstrated between race and a particular finding, this becomes a medical fact without any further investigation. Traditionally, epidemiological studies begin with a statement regarding the age, race and sex predilection of the topic being considered. The current investigation demonstrates the naivete of such an approach. Race differences (and possibly many sex-related differences) should be generalized to a particular group only after careful consideration of the biological mechanisms and exclusion of confounding influences. The current investigation was able to demonstrate that differences in lung function in different race groups are due in part, if not completely, to the relationship of race to social stratification.

It is important to realize that, throughout the world, similar race groups occupy similar social stratification positions. Biological differences may thus be consistently demonstrated in different "race" groups and the effects spuriously attributed to genetic rather than socio-environmental influences. In societies moving towards racial desegregation, the onus rests with medical investigators to re-examine the issue so that fallacious associations are not perpetuated.

An urgent issue that is facing medicine is the need to widen the concepts regarding the relationship of illness, health and social stratification influences. It is necessary that the current tenets of race and socio-economic classifications be subjected to more insightful investigations. It is highly probable that such an approach will break down racial prejudices and improve our medical management of different population groups. Preventative health measures will also be improved by focussing these measures on social stratification influences rather than on populations defined by race.

With regard to lung function surveys, longitudinal studies should be established in areas where stable populations exist and where the influence of social stratification can be scientifically evaluated. Our understanding of lung function will be developed by such studies, not only in relation to social stratification but also in relation to the effects of anthropometric measurements and age.

2. Clinical and epidemiological practice

The utility of prediction equations depends on the discipline concerned. In routine clinical practice normal spirometric predicted values are essential in the evaluation of an individual. Perhaps the best approach at present would be to adopt the predicted values derived from individuals belonging to the highest social stratification group as the set of normal values. A patient's lung functions should be compared to predicted normals derived from a normal population of the same race group as the patient concerned. This would be similar to the practice of using of different prediction equations for gas transfer for different smoking categories so that the effect in order to detect the presence of other disease processes in addition to smoking. One does not wish to imply in the latter approach that smoking is a "normal" phenomenon, but rather that this is practical in the clinical setting. Similarly, different race predictors do not imply acceptance of genetic/race differences, but offers a practical solution to a very complex question. Although race predictors may exist in the clinical laboratory, they should only be considered in this setting as a temporary measure, pending more information from future statistics aimed at separating the influences of genetic "racial" versus socio-environmental racial influences.

In epidemiological and occupational health screening the comparison of lung function measurements with external "normal values" is less useful because of variables such as apparatus related differences. In the occupational setting screening programmes including pre-employment screening would be valuable, so that an individuals lung functions can be monitored against his/her own reference values.

3. Preventative health

The use of race specific predictors should be discarded. Underpinning this view is the awareness that if blacks have smaller lungs because of socio-environmental influences (rather than genetic), society's responsibility to improve conditions will not cease until the biological effects of such influences have disappeared. This concept is most vividly exemplified by the belated adoption of universal growth charts for children of all races in South Africa²¹¹, whereas previously it was assumed that there was a genetic

basis for the slower growth rate of black children (compared to white), the realization that these observations had socio-environmental factors as their root-cause led to intensified educational and nutritional programmes. Preventative respiratory health measures should be instituted wherever population groups are demonstrated to differ from a universal standard base (as discussed above). Strategies for preventative health measures will also be improved if they focussed on the causes and effects of social stratification. Clear descriptions of the socio-environmental effects of lung function (as attempted in the present project), perinatal mortality, nutritional and infectious diseases, etc. will undoubtedly enhance the health planners' ability to formulate rational preventative strategies.

4. Legislation

The data in the present study calls into question the appropriateness of racially-linked normative spirometric values, particularly when they are applied to the assessment of impairment in compensation legislation. As matters stand now in South Africa, it is possible that a black man with a moderately reduced FVC may not receive compensation for impairment as calculated from the "normal value for blacks", but may qualify if the calculation was based on the "normal value for whites". We believe that the assumption that blacks have smaller lungs for genetic reasons may well be spurious, and the data in this study would suggest that socio-environmental influences play (at least) an equally important role.

It seems unjust that on this issue, where it cannot be said that genetic influences (related to skin colour) on lung function are the cause, beyond reasonable doubt, of smaller lungs in blacks, legislation should disadvantage the plaintiff. We believe that the authorities concerned with compensation should take cognisance of the great measure of uncertainty regarding the racial-genetic influence on lung spirometry (as embodied in this thesis); until more definitive evidence in favour of the racial-genetic hypothesis is produced, black workers should be given the benefit of the doubt by having their impairment assessed against the same normative values that are used for white workers.

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UNIVERSITY OF CAPE TOWN



Department of Medicine

Medical School · Observatory 7925 Cape South Africa
Telephone 47-1250

Issued from the Respiratory Unit.

March 11th , 1987

LUNG FUNCTION SURVEY

Dear Sir ,

The lung function of normal adults has never been satisfactorily documented in South Africa . If accurate lung function tests could be obtained ,doctors and research workers would be able to assess and treat the abnormalities of patients and disabled persons .We should like to perform simple tests ,requiring you to blow into a machine in order to measure the lung functions of a large group of normal people who work in a "clean-air" environment.

Since we can not study all Barclays employees , you were selected by a scientific method and your cooperation is very important to the success of the study.

We would be most grateful if you would agree to help us with this survey . It is important that every selected individual takes part ,because we must know the average value for all age groups .

In order to help us in the study , would you kindly answer the attached few questions and bring the form to your "section head"at work tomorrow. Your answers will be held in confidence by the medical research workers concerned.

Thank you for your help . We'll let you know when the survey is due to take place !

Yours sincerely ,

 Signed

DR. JONATHAN GOLDIN
DEPARTMENT OF RESPIRATORY MEDICINE

 Signed

ROD CUSENS
MANAGER- SOCIAL RESPONSIBILITY



APPENDIX II

Survey
No.

BARCLAYS LUNG FUNCTION SURVEY POSTAL QUESTIONNAIRE

1. My name is.....
2. My current age is.....years
3. I grew up in.....(State suburb name)
4. I have lived in Johannesburg for.....years
5. I never smoked cigarettes/I have stopped smoking/still smoke
(please circle the right answer)
6. I am willing to do a simple lung function test performed at
Barclaycard Centre. Yes/No (please circle the right answer)
(Transport will be provided)
7. I am willing to have an X-ray of my chest. Yes/No (Please
circle the right answer)

Thank you for your help. Please place this questionnaire in an envelope (for internal office use) and return it to John van Dyk, Group Assistant Secretary, Barclays Head Office, T & S (84 Market Street, Johannesburg.



BARCLAYS LUNG FUNCTION SURVEY

(MAY - JULY 1987, BARCLAYCARD CENTRE)

- THE LARGEST PROPOSED STUDY OF ITS KIND.
 - PARTICIPATION BY THOSE SELECTED IS ESSENTIAL.
 - ALL INFORMATION HELD IN CONFIDENCE BY MEDICAL TEAM.
- (University of Cape Town's Respiratory Unit)

AIM

TO DOCUMENT LUNG FUNCTION OF NORMAL ADULTS IN SOUTH AFRICA.

WHY

ANTICIPATED RESULTS WOULD HAVE IMMEDIATE AND BENEFICIAL EFFECT ON

- 1) ASSESSMENT AND TREATMENT ON LUNG DISEASES (A MAJOR CAUSE OF DEATH AT ALL AGES IN S.A.).
- 2) IDENTIFYING THOSE FACTORS ASSOCIATED WITH GOOD HEALTH (e.g. NUTRITION) AND THOSE ASSOCIATED WITH LUNG DISEASE (e.g. AIR POLLUTION).
- 3) THOSE AT RISK FROM OCCUPATIONAL LUNG DISEASE (e.g. DUSTY JOBS).

"Health is a precious thing, and the only one, in truth, meriting that a man should lay out, not only his time, sweat, labour, and goods, but also his life itself to obtain it".

Montaigne



SURVEY NO:

SURVEY CARD NO:

UNIVERSITY OF CAPE TOWN RESPIRATORY DEPARTMENT
LUNG FUNCTION SURVEY
QUESTIONNAIRE

Thank you for your willingness to participate. You were selected by a scientific method and your co-operation is very important to the success of the study.

This survey involves answering questions about your health and occupation(s). It is part of a survey to document the lung functions of normal adults which have never been satisfactorily documented in South Africa.

Please answer the questions as frankly and accurately as possible. All INFORMATION OBTAINED IN THIS STUDY WILL BE KEPT CONFIDENTIAL AND USED FOR MEDICAL RESEARCH ONLY. You will be provided with a report as soon as possible which you can discuss with your doctor if necessary.

A) EMPLOYEES:

SURNAME MIDDLE FIRST

B) INTERVIEWER:

CARD NO _ _ _ _

CODING PURPOSES

SURVEY CARD NO
Identity No
COMPUTER CARD

CODE NO

1-4

1

A. IDENTIFICATION DATA

1. Surname _____ First Name _____

2. Address _____

3. Telephone number _____ Work number _____
Ext. No _____

4. Date of birth _____
Month Day Year

5. Age at next birthday ___ (Years)

6. Sex: 1) Male
2) Female

7. Ethnic Group 1) Black 2) White 3) Coloured 4) Asian

8. Home language:

- 1) Afrikaans
- 2) English
- 3) Tswana
- 4) Xhosa
- 5) Zulu
- 6) Sotho
- 7) Venda
- 8) Other _____ State

9. Marital status:

- 1) Single
- 2) Married
- 3) Widowed
- 4) Separated/Divorced

10. Interviewer number _____

11. Date:

B. CHILDHOOD DATA

I am going to ask you some questions about your childhood, and your family.

12. Were you born in an urban or rural area?

- | | | |
|----------|-----------|---------|
| | City/Town | Suburb |
| 1. Urban | ----- | ----- |
| | Area | Village |
| 2. Rural | ----- | ----- |

13. Did you grow in an urban or rural area (that is between 0 - 15 years)?

- | | | | |
|----------|-----------|---------|-------|
| 1. Urban | Town/City | Suburb | Ages |
| | ----- | ----- | ----- |
| | ----- | ----- | ----- |
| | ----- | ----- | ----- |
| 2. Rural | Area | Village | Ages |
| | ----- | ----- | ----- |
| | ----- | ----- | ----- |
| | ----- | ----- | ----- |

If answer to 13 is rural then ask question 14

14. Did your mother spend much of her time crushing maize for household use?

- 1) Yes
- 2) No
- 3) Unsure
- 4) Does not apply

15. What type of work did your father do?

- 1. _____
- 2. Received grant (specify:) _____
- 3. Did not receive any income

CARD NO

CODE NO

16. What type of work did your mother do?

- 1. Housework alone with no income
- 2. Housework together with other job (specify.....)
- 3. Other work (specify.....)
- 4. Received grant (specify.....)

17. Was your father away from home for long periods of time ie for more than 6 months every year?

- 1) Yes
- 2) No
- 3) Unsure
- 4) Does not apply

18. Were you breast fed as a baby?

- 1) Yes
- 2) No
- 3) Do not know

19. Were you vaccinated as a child?

- 1) Yes
- 2) No
- 3) Do not know

20. How many brothers and sisters (biological siblings) did you have (include any that may have died).
_____ (number)

21.A Did any of your brothers or sisters die during their childhood?

- 1) Yes
- 2) No
- 3) Don't know

If Yes to 21.A	
B) How many	___ (number)
C) What was the cause of death	
1)	___ (specify)
2)	___ (specify)
3)	___ (specify)

CARD NO

CODE NO

22. How many children grew up in the house/home you usually lived in as a child _____ (number) _ _

23. As a child, when you were ill, did your parents (guardians) take you to a medical person.

- 1) Yes
- 2) No
- 3) Do not know

If yes to 23 A

B) Who did they usually take you to:

- 1) Clinic (sister only)
- 2) Day hospital (sisters and doctors)
- 3) General hospital
- 4) Private Practitioner
- 5) Traditional (tribal) healer
- 6) Chiropractor, herbalist

24. Do you remember whether the home in which you lived in for the longest as a child was

- 1) Rented/state owned
- 2) Rented/employer owned
- 3) Rented/private owned
- 4) Owned by your family
- 5) Free dwelling squatter camp
- 6) Free dwelling domestic servant
- 7) Don't remember

25. Do you remember whether the home in which you as a child lived in for the longest was

- 1) A house
- 2) Semi-detached/townhouse
- 3) A flat
- 4) Hotel
- 5) Hostel
- 6) Shack
- 7) Other eg kraal/.....
- 8) Don't remember

26. How many people usually lived in your childhood home until you were 15 years old?

_ _ _ (Number) _ _

CARD NO

CODE NO

27. How many rooms apart from the kitchen,
bathroom and toilet were there in
in the home you usually lived in as a child?
_ _ _ (Number)

--

28. How was your home usually heated?
(when you were a child)

- 1) Open fire with a chimney
- 2) Open fire without a chimney
- 3) Anthracite stove
- 4) Electric unit
- 5) Not heated
- 6) Other _ _ _ _ _ specify

--

29. What fuel was usually used for heating
in the home you lived in as a child?

- 1) Wood
- 2) Coal or coke
- 3) Paraffin
- 4) Electricity
- 5) Gas
- 6) Dung
- 7) Does not apply
- 8) Other _ _ _ _ _ specify

--

30. What fuel was usually used for cooking in
the home in which you lived as a child?

- 1) Coal or coke
- 2) Wood
- 3) Gas
- 4) Electricity
- 5) Fire oil kerosene
- 6) Paraffin
- 7) Other _ _ _ _ _ specify

--

31. What is the highest standard you completed
in school? _ _ _ (state highest standard)

--

CARD NO

CODE NO

32. What is the highest education you have completed since leaving school?

- 1) Nil
- 2) Apprentice
- 3) Teacher training diplomas
- 4) Technicon diplomas
- 5) Bankers' exam
- 6) University graduate
- 7) Post graduate studies
- 8) Other _ _ _ _ _ specify

C. ADULT DATA

C. 1 I would now like to ask you a few questions about your previous jobs.

33. Have you ever

A. Worked with asbestos
(in a mine or factory)?

- 1) Yes
- 2) No
- 3) Don't know

B. Worked in a mine?

- 1) Yes
- 2) No
- 3) Don't know

C. Worked in a foundry?

- 1) Yes
- 2) No
- 3) Don't know

D. Worked in a quarry?

- 1) Yes
- 2) No
- 3) Don't know

CARD NO

CODE NO

E. Worked in any other place, with dust, smoke or chemical fumes?

- 1) Yes
- 2) No
- 3) Don't know

F. Worked in a grain mill or bakery?

- 1) Yes
- 2) No
- 3) Don't know

G. Done any work other than at the First National Bank?

- 1) Yes
- 2) No
- 3) Don't know

-
-
-

55

If yes to any or more than one of above (33A-G)

Please give a) name of company/mine/factory etc

- i) _____
- ii) _____
- iii) _____
- iv) _____

b) job(s)/position(s) held

- i) _____
- ii) _____
- iii) _____
- iv) _____

c) no. of years worked

- i) _____
- ii) _____
- iii) _____
- iv) _____

CARD NO

CODE NO

34. A. Have you ever worked in a dusty job

- 1) Yes
- 2) No

If yes to 34A

B. Was this dusty job

- 1) one of the jobs mentioned above in 33A-G
- 2) Other _ _ _ _ _ specify

C. Could you see dust while working

- 1) Yes
- 2) No
- 3) Does not apply

D. Would you say the job was usually

- 1) Slightly dusty
- 2) Dusty
- 3) Very dusty
- 4) Does not apply

C. 2 I would now like to ask you about your work at the First National Bank

35. How long have you been working at the First National Bank?
___ years

36. What type of work do you currently do here?

- 1) Messenger
- 2) Catering
- 3) Cleaner
- 4) Driver
- 5) Security
- 6) Other non clerical
- 7) Clerical/Administrative
- 8) Teller
- 9) Management
- 10) Other _ _ _ _ _ specify

37. For how long have you been doing this type of work
___ years

CARD NO

CODE NO

38. Before doing this job what other jobs have you done with the First National Bank?

If Yes please specify

Job	Years
1) -----	-----
2) -----	-----
3) -----	-----
4) -----	-----

39. Are you married?

- 1) Yes
- 2) No

If yes to 39

40. Does your wife earn an income

- 1) Yes
- 2) No
- 3) Does not apply

41. Do any of your children work and contribute to your household earnings?

- 1) Yes
- 2) No
- 3) Does not apply

42. A. Do you have additional sources of income Other than those above?

- 1) Yes
- 2) No

If yes to any of 40, 41 or 42A.

42. B. What is your combined monthly income?

- 1) Less than 800 Rands
- 2) Between 801 - 1000 Rands
- 3) Between 1001 - 2000 Rands
- 4) Between 2001 - 3000 Rands
- 5) More than 3000 Rands
- 6) Does not apply

68

CARD NO

CODE NO

43. How many dependents do you have?
 (include all children and other people
 less than 15 years or greater than
 60/65 years or crippled or unemployed
 who depend on you for financial support)
 - - - - - number

- - 70

NEXT CARD

C. 3 I am now going to ask you questions
 about your health. These questions
 pertain mainly to your chest. Please
 answer yes or no if possible.

COUGH

Identity No
Card

44. A Do you usually have a cough? (Count a
 cough with first smoke or on first
 going out-of-doors. Exclude clearing
 of throat.)

- - - -
2

(If NO, skip to Question 44C)

- 1) Yes
- 2) No

B Do you usually cough as much as 4 to 6
 times a day, 4 or more days out of the
 week?

- 1) Yes
- 2) No

C Do you usually cough at all on getting
 up, or first thing in the morning?

- 1) Yes
- 2) No

D Do you usually cough at all during the
 rest of the day or at night?

- 1) Yes
- 2) No

- 9

CARD NO

CODE NO

IF YES TO ANY OF ABOVE (44A,B,C,OR D), ANSWER THE FOLLOWING:

IF NO TO ALL, CHECK DOES NOT APPLY AND SKIP TO NEXT QUESTION.

E Do you usually cough like this on most days for 3 consecutive months or more during the year?

- 1) Yes
- 2) No
- 3) Does not apply

F For how many years have you had this cough?

- 1) Number of years _____
- 2) Does not apply _____

PHLEGM

45. A Do you usually bring up phlegm (count phlegm with the first smoke or on first going out-of doors. Exclude phlegm from the nose. Count swallowed phlegm.)

- 1) Yes
- 2) No

(If no, skip to 45C)

B Do you usually bring up phlegm like this as much as twice a day, 4 or more days out of the week?

- 1) Yes
- 2) No

C Do you usually bring up phlegm at all on getting up, or first thing in the morning?

- 1) Yes
- 2) No

CARD NO

CODE NO

D Do you usually bring up phlegm at all during the rest of the day or night?

- 1) Yes
- 2) No

IF YES TO ANY OF THE ABOVE (45A, B, C OR D),
ANSWER THE FOLLOWING:
IF NO TO ALL, CHECK DOES NOT
APPLY AND SKIP TO NEXT QUESTION

E Do you bring up phlegm like this on most days for 3 consecutive months or more during the year?

- 1) Yes
- 2) No
- 3) Does not apply

F For how many years have you had trouble with phlegm?

- 1) Number of years _____
- 2) Does not apply

EPISODES OF COUGH AND PHLEGM

46. A Have you had periods or episodes of (increased*) cough and phlegm lasting for three weeks or more each year? *(For persons who usually have cough and/or phlegm)

- 1) Yes
- 2) No

IF YES TO 46A:

B For how long have you had at least 1 such episode per year?

- 1) Number of years _____
- 2) Does not apply _____

CARD NO

CODE NO

WHEEZING

47. A Does your chest ever sound wheezy or whistling:

1. When you have a cold?

- 1) Yes
- 2) No

2. Occasionally apart from colds?

- 1) Yes
- 2) No

3. Most days or nights

- 1) Yes
- 2) No

IF YES TO 1, 2 OR 3 IN 47A:

B. For how many years has this been present?

- 1) Number of years ___
- 2) Does not apply _____

48. A Have you ever had an attack of wheezing that has made you feel short of breath?

- 1) Yes
- 2) No

-

-

-

- -

-

CARD NO

CODE NO

IF YES TO 48A:

B How old were you when you had your first such attack?

- 1) Age in years _____
- 2) Does not apply _____

C Have you had 2 or more such episodes?

- 1) Yes
- 2) No
- 3) Does not apply

D Have you ever required medicine or treatment for the (se) attack (s)?

- 1) Yes
- 2) No
- 3) Does not apply

E Are you currently requiring to take medicines for these attacks?

- 1) Yes
- 2) No
- 3) Does not apply

BREATHLESSNESS

49. If disabled from walking from any condition other than heart or lung disease, please describe and proceed to Question 51A

Nature of condition(s): _____

50. A Are you troubled by shortness of breath when hurrying on the level or walking up a slight hill?

- 1) Yes
- 2) No

35

CARD NO

CODE NO

IF YES TO 50A:

B Do you have to walk slower than people of your age on the level because of breathlessness?

- 1) Yes
- 2) No
- 3) Does not apply

C Do you ever have to stop for breath when walking at your own pace on the level?

- 1) Yes
- 2) No
- 3) Does not apply

D Do you ever stop for breath after walking about 100 yards (or after a few minutes) on the level?

- 1) Yes
- 2) No
- 3) Does not apply

E Are you too breathless to leave the house or breathless on dressing or undressing?

- 1) Yes
- 2) No
- 3) Does not apply

39

CARD NO

CODE NO

CHEST COLDS AND CHEST ILLNESSES

51 A Do you have a cold or flu today.

- 1) Yes
- 2) No

51 B If you get a cold does it usually go to your chest?
(Usually means more than + 50%)

- 1) Yes
- 2) No
- 3) Don't get colds

52 A During the past 3 years, have you had any chest illnesses that have kept you off work, indoors at home, or in bed?

- 1) Yes
- 2) No

IF YES TO 52A:

B Did you produce phlegm with any of these chest illnesses?

- 1) Yes
- 2) No
- 3) Does not apply

C In the last 3 years, how many such illnesses with (increased) phlegm, did you have which lasted a week or more?

- 1) Number of illnesses ____
- 2) No such illnesses _____
- 3) Does not apply _____

44

CARD NO

CODE NO

PAST ILLNESSES

53 Did you have any lung trouble before the age of 16?

- 1) Yes
- 2) No

54 Have you ever had any of the following?

1A Attacks of bronchitis?

- 1) Yes
- 2) No

IF YES TO 1A

B Was it confirmed by a doctor?

- 1) Yes
- 2) No
- 3) Does not apply

C At what age was your first attack

- 1) Age in years _____
- 2) Does not apply _____

2A Pneumonia (include bronchopneumonia?)

- 1) Yes
- 2) No

CARD_NO

CODE NO

IF YES TO 2A:

Was it confirmed by a
doctor

- 1) Yes
- 2) No
- 3) Does not apply

At what age did you first
have it?

- 1) Age in years ___
- 2) Does not apply ___

3A Hay fever?

- 1) Yes
- 2) No

IF YES TO 3A:

Was it confirmed

- 1) Yes
- 2) No
- 3) Does not apply

At what age did it start

- 1) Age in years ___
- 2) Does not apply ___

55 Have you ever had chronic
bronchitis?

- 1) Yes
- 2) No

58

CARD NO

CODE NO

IF YES TO 55A

B Do you still have it?

- 1) Yes
- 2) No
- 3) Does not apply

C Was it confirmed by a doctor?

- 1) Yes
- 2) No
- 3) Does not apply

D At what age did it start?

- 1) Age in years
- 2) Does not apply

56A Have you ever had emphysema?

- 1) Yes
- 2) No

IF YES TO 56A

B Do you still have it?

- 1) Yes
- 2) No
- 3) Does not apply

C Was it confirmed by a doctor?

- 1) Yes
- 2) No
- 3) Does not apply

D At what age did it start?

- 1) Age in years__
- 2) Does not apply__

67

IDENTITY NO

CARD

3

57A Have you ever had asthma?

- 1) Yes
- 2) No

-

IF YES TO 57A

B Do you still have it?

- 1) Yes
- 2) No
- 3) Does not apply

-

C Was it confirmed by a doctor?

- 1) Yes
- 2) No
- 3) Does not apply

-

D At what age did it start

__ (age in years)

--

E If you no longer have it,
at what age did it stop?

__ (age in years)

--

58A Have you ever had pulmonary TB
(ie TB of the lung)

- 1) Yes
- 2) No
- 3) Don't know

-

CARD NO

CODE NO

IF YES TO 58A

B Do you still have it

- 1) Yes
- 2) No
- 3) Do not know

C Was it confirmed by a doctor or TB clinic

- 1) Yes
- 2) No
- 3) Do not know

D Did you receive treatment for

- 1) <6 months treatment
- 2) 7 months to 1 year
- 3) > 1 year treatment
- 4) Don't remember

E How many different medicines (include injections) did the treatment include

- 1) Two or less different drugs
- 2) Three or more different drugs
- 3) Do not remember

F How many episodes of TB have you had

- 1) 1
- 2) 2
- 3) 3
- 4) more than 3

G How old were you when you first had TB

- 1) Age in years _____
- 2) Does not apply

20

CARD NO

CODE NO

59 Have you ever had:

A Any other chest illness?

- 1) Yes
- 2) No
- 3) If yes, please specify _____

B Any chest operations?

- 1) Yes
- 2) No
- 3) If yes, please specify _____

C Any chest injuries?

- 1) Yes
- 2) No
- 3) If yes, please specify _____

60 A Has a doctor ever told you
that you had heart trouble

- 1) Yes
- 2) No

IF YES TO 60A:

B Have you ever had treatment
for heart trouble in the past
10 years?

- 1) Yes
- 2) No
- 3) Does not apply

C Has a doctor ever told you that
you had high blood pressure?

- 1) Yes
- 2) No

26

CARD NO

CODE NO

IF YES TO 60C

D Have you had any treatment for high blood pressure (hypertension) in the past 10 years?

- 1) Yes
- 2) No
- 3) Does not apply

C4 I am now going to ask you questions about smoking.

61A Have you ever smoked cigarettes (no means less than 1 cigarette a day for 1 year)

- 1) Yes
- 2) No

IF YES TO 61A

B Do you smoke more than 10 cigarettes a day at present?

- 1) Yes (state how many _____)
- 2) No

IF NO TO 61B

C Do you smoke less than 10 cigarettes a day

- 1) Yes
- 2) No

D How long ago did you stop smoking?
____ years

33

CARD NO

CODE NO

62. Do you smoke a pipe?
1) Yes
2) No
63. Do you smoke any other leaves?
(eg dagga, cigars etc)
1) Yes (state what leaves _____)
2) No
- 64A Does anyone else in your house
(beside yourself)
- 1) Smoke more than 10 cigarettes a day?
1) Yes
2) No
- 2) Smoke a pipe?
1) Yes
2) No
- 3) Other leaves?
1) Yes (state what leaves _____)
2) No
- 64B When you were a child
did anyone in your family home
- 1) Smoke more than 10 cigarettes a day?
1) Yes
2) No
- 2) Smoke a pipe?
1) Yes
2) No
- 3) Other leaves?
1) Yes
2) No

CARD NO

CODE NO

C4. The last group of questions I am going to ask you relate to your accommodation.

65. How long have you lived in your current residence? ____years

If less than 10 years

66. How many changes (changes of suburb) have you had in the last 10 years? ____ (number)

67. How much of your adult life has been spent living in an urban area (that is a town or city)

- 1) All my adult life
- 2) More than half my adult life
- 3) Less than half my adult life

Please specify

i) Towns _____ _____ _____

ii) Suburbs _____ _____ _____

iii) Years _____ _____ _____

68. Is your home

- 1) rented/state owned
- 2) rented/company owned
- 3) rented/private owned
- 4) owned by you and fully paid off
- 5) owned by you but still being paid off
- 6) free accomodation squatter camp
- 7) free accomodation domestic servant

69. Is your home a

- 1) house
- 2) semi detached
- 3) flat
- 4) hostel
- 5) shack

__ _ 17: 1

__ _ 17: 3

-

-

-

CARD NO

CODE NO

70. What fuel is used for cooking

- 1) Coal or coke
- 2) Gas
- 3) Paraffin
- 4) Wood
- 5) Electricity
- 6) Other (specify _____)

71. Do you have any pigeons, budgies, canaries or other birds at home?

- 1) Yes
- 2) No

THANK YOU FOR YOUR COOPERATION.

OFFICIAL USE

RRR _____

GGG _____

-

-

-

- -

APPENDIX V

Simkins Code	Barclays Survey Code	Occupation
01;02	1	Independent and high professional, executives and high administrative in large organisations.
03;04	2	Professional and salaried professional, lower executives and similar administratives in large firms, civil service and executives in medium firms.
05	3	Semi-professional, creative and programmers.
06A;06B	4	Owners and executives in small private firms. Senior clerical and white-collar technical.
07	5	Clerical, sales representatives.
08A;08B;09;10	6	Blue-collar technical, supervisory and inspectional and skilled manual, routine non-manual, ranks in services, street and market traders.
11	7	Semi-skilled.
12	8	Unskilled.
	9	Non-contributory to work force.