A STUDY OF THE REPRODUCIBILITY OF THE FORCED VITAL CAPACITY OF COALWORKERS AT TWO COLLIERIES IN SCOTLAND AND TWO COLLIERIES IN SOUTH WALES

BY

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From the National Coal Board, Pneumoconiosis Field Research

(RECEIVED FOR PUBLICATION JUNE 4, 1959)

A study of 1,522 coalworkers at two Scottish collieries and two Welsh collieries showed that the forced vital capacity (F.V.C.) was as reproducible a measurement as the forced expiratory volume (F.E.V.) (1 sec.). This applied not only to replicate readings, but also between readings taken before and after a working shift on the same day, and also between readings taken at an interval of one week. An examination of the results of F.E.V. (1 sec.) and F.V.C. readings taken on the entire colliery populations at a colliery in Ayrshire, Scotland, and one in South Wales showed that replicate readings of F.V.C. and F.E.V. (1 sec.) were equally reproducible and that reproducibility was virtually unaffected by the presence or absence of bronchitic symptoms or the different prevalence of pneumoconiosis at the two collieries.

In the investigations into the lung function of coalworkers by the Pneumoconiosis Field Research of the National Coal Board (Fay, 1957) measurements are taken of the forced vital capacity, the total volume of air which can be forcibly expired after a maximal inspiration (F.V.C.), and the forced expiratory volume (F.E.V., 1 sec.), that is, the fraction of the forced vital capacity which has been expired in the first second. Both measurements have been carried out by the single-breath technique

The use of F.E.V. (1 sec.) as an index of breathlessness is well established. Kennedy (1953) found that the indirect maximum breathing capacity obtained by multiplying the F.E.V. (0.75 sec.) by 40 correlated highly with, and was numerically similar to, the direct maximum breathing capacity. Gilson, Hugh-Jones, Oldham, and Meade (1955) showed that the maximum breathing capacity was highly correlated with independent clinical assessment of breathlessness among coalworkers, and Gilson (1958) pointed out that the correlation coefficient of F.E.V. (0.75 sec.) and F.E.V. (1 sec.) was 0.996.

On the other hand, the use of the F.V.C. in the assessment of lung function either alone or in combination with F.E.V. has by no means obtained universal approval. The reason for this is mainly the fact that severely disabled men may have a normal or nearly normal F.V.C. but a greatly

reduced F.E.V. (1 sec.). Doubts also exist regarding the reproducibility of the F.V.C. It is important in any study of vital capacity to state clearly the method used in its measurement, as even in the same subject the method used may have a great influence on the result obtained.

Comroe, Forster, Dubois, Briscoe, and Carlsen (1955) stated that vital capacity, even with a standardized method of measurement, may vary by as much as 200 ml. in the same subject when replicate readings are taken. Christie (1932) goes so far as to say that forced vital capacity involves the use of "respiratory gymnastics" never undertaken even in the severest exercise. Christie was of the opinion that vital capacity varied even in normal subjects with replicate readings and considered it to be of limited use for the measurement of deviation from the normal.

Thus, one of the main criticisms of the use of the F.V.C. as an index of lung function is that it may not be as reproducible as the F.E.V. This paper gives the results of an investigation into the reproducibility of the F.V.C., using data from surveys of coalworkers at two collieries in Scotland and two in South Wales.

Method

The apparatus used in this study was the modified spirometer described by McKerrow, McDermott, and

Gilson (1960), except that the wheel of the spirometer head was graduated in litres and thus readings of F.E.V. and F.V.C. could be made directly rather than having the wheel marked to record indirect M.B.C. as in the apparatus used by McKerrrow and his colleagues.

The instructions given to each subject were to take as deep a breath as possible and then to blow into the spirometer mouthpiece as hard and as fast as possible until expiration was complete.

Data concerning F.E.V. and F.V.C. measurements are available from two sources. The first of these is the pilot trials which were undertaken at Colliery A in Fife, Scotland, and Colliery B in South Wales (Ashford, Forwell, and Routledge 1960). The primary purpose of these pilot trials was to determine whether the working of a shift had any effect on the performance of lung function tests. The men were divided into two groups according to their answers to a respiratory symptoms questionnaire, *viz.*, those with and those without bronchitic symptoms. The pilot trials took place over a period of two weeks. At each colliery a random sample of 75 men balanced for age and occupation was examined before and after a working shift on a specified day in the first week of the trial, and again on a specified day in the second week. On each of the four visits six replicate readings were made of F.E.V. (1 sec.) and F.V.C.

The second source of information was the routine physiological surveys at Colliery C, Ayrshire, Scotland, and Colliery D, South Wales, at each of which over 95% of the working population was examined. Each man made only one visit at which four replicate readings of F.E.V. (1 sec.) and F.V.C. were made. The population examined at Colliery D numbered 519 men and that at Colliery C 853 men.

Results

Reproducibility of the F.V.C.—The two criteria for satisfactory reproducibility of a measurement such as F.E.V. or F.V.C. must be considered. In the first place, the subject's performance must be consistent on successive forced expirations on the same occasion. Secondly, if the subject's average performance over a number of forced expirations is consistent from day to day and from time to time during the same day, then this is further evidence for reproducibility, although a significant change in the value of F.E.V. and F.V.C. might indicate a true change in lung function, as was found in McKerrrow's studies of byssinosis (McKerrrow, McDermott, Gilson, and Schilling, 1958). Our results provide some information about both these aspects of reproducibility.

Comparison of corresponding values of F.E.V. and F.V.C. on successive expirations during the same examination showed no evidence that the variability of the results was directly related to their absolute values. The reproducibility of the measurements of F.E.V. and F.V.C. has therefore been expressed in terms of the standard deviation of the

individual observations rather than, say, the coefficient of variation. When considering these results it should be borne in mind that the average absolute values of the F.E.V. vary from about 2 to 4 litres, and the average absolute values of the F.V.C. from about 3 to 5½ litres. On average, the F.E.V. (1 sec.) accounts for about 75% of the F.V.C.

On analysis of results obtained at Colliery A and Colliery B, the first measurement of both F.E.V. and F.V.C. at each examination was consistently lower than the remainder. This rise in F.E.V. and F.V.C. between the first and subsequent readings is referred to as the "learning effect", and the observations made on the first expiration on each occasion have been discarded.

The standard deviations of the F.V.C. and the F.E.V. from expiration to expiration at the same examination are given in Table 1(a), which is subdivided according to the examination at which the readings were made. At both collieries the variability of the F.V.C. is only slightly greater than that of the F.E.V. When the results of the readings obtained at the first examination are considered there is no evidence of any appreciable difference in the reproducibility of the F.V.C. and the F.E.V. at either colliery. There is a marked tendency for the reproducibility of both F.E.V. and F.V.C. to increase as the subject becomes more experienced in the use of the apparatus, once again due possibly to a "learning effect".

Because of this significant rise in reading of F.E.V. (1 sec.) and F.V.C. after the first reading, the first F.E.V. (1 sec.) and F.V.C. on the surveys at Colliery C and Colliery D were discarded. The results obtained on the "routine" surveys at Colliery C and Colliery D are summarized in Table 1 (b), which is subdivided in terms of the men

TABLE 1
REPRODUCIBILITY OF F.E.V. AND F.V.C. MEASUREMENTS
FROM EXPIRATION TO EXPIRATION AT THE SAME
ATTENDANCE

Standard Deviation of a Single Expiration (l.)

(a) Pilot Trials

Colliery	Attendance	1	2	3	4	All
A 75 men	F.V.C.	0.15	0.14	0.13	0.13	0.14
	F.E.V.	0.15	0.14	0.12	0.11	0.13
B 75 men	F.V.C.	0.20	0.22	0.16	0.14	0.18
	F.E.V.	0.20	0.19	0.13	0.12	0.17

(b) Routine Surveys (one examination only)*

Colliery	Bronchitic Symptoms	With	Without	All
C	F.V.C.	0.19	0.15	0.15
	F.E.V.	0.16	0.14	0.15
D	F.V.C.	0.16	0.15	0.15
	F.E.V.	0.15	0.15	0.15

*The results of the initial expiration on each attendance have been discarded.

with and without bronchitic symptoms. Those men who are found to have cough or sputum, plus breathlessness, wheeze, or a history of absence from work due to chest illness during the preceding three years, or a positive correlation between weather and chest symptoms, are classified as having "bronchitic symptoms". Those who do not satisfy these criteria are classified as not having "bronchitic symptoms".

When the whole population is considered there is no appreciable difference between the reproducibility of the F.E.V. and the F.V.C. measurements at either Colliery C or Colliery D, although there is a suggestion that amongst the men with bronchitic symptoms the F.V.C. is slightly less consistent.

Information about reproducibility from time to time during the same day and from day to day may be obtained from the results of the pilot trials, when each man was examined before and after the working shift on a specified day in both the first and second weeks. The variability of the observations between the beginning and end of shift on the same day is summarized in Table 2. The standard deviations

TABLE 2

REPRODUCIBILITY OF F.E.V. AND F.V.C. MEASUREMENTS BETWEEN BEGINNING AND END OF A WORKING SHIFT (BASED ON RESULTS OF PILOT TRIALS)

Standard Deviation of a Single Expiration (l.)

Colliery	A	B
F.V.C.	0.33	0.39
F.E.V.	0.31	0.33

given in Table 2 represent a summation of the variability from expiration to expiration on the same occasion (Table 1a) and the variability in average performance between the beginning and end of shift. They are therefore greater than the corresponding values given in Table 1(a) which represent only the former source of variability. At Colliery A the F.E.V. is only slightly less variable than the F.V.C., but at Colliery B there is a definite suggestion that the F.E.V. is more reproducible. When the variability from day to day is considered (Table 3) similar differences are apparent. The

TABLE 3

REPRODUCIBILITY OF F.E.V. AND F.V.C. MEASUREMENTS BETWEEN SUCCESSIVE WEEKS (BASED ON RESULTS OF PILOT TRIALS)

Standard Deviation of a Single Expiration (l.)

Colliery	A	B
F.V.C.	0.37	0.69
F.E.V.	0.34	0.46

standard deviations given in Table 3 represent a summation of the variability from day to day, between the beginning and end of the shift on the same day, and from expiration to expiration on the same occasion. A comparison with Table 2 suggests that, while variation both in F.E.V. and F.V.C. from day to day at Colliery A is small, that at Colliery B is larger, and the F.V.C. is the more variable of the two measurements. The absolute value of F.V.C. measurement is, of course, greater than that of F.E.V., and if this fact is taken into account, it is apparent that the proportional variation of F.V.C. is very little different and, if anything, slightly smaller than that of the F.E.V. and that in spite of differences in the prevalence of radiological pneumoconiosis at the collieries investigated (at Colliery C, 14.5%, and at Colliery D, 36.9%) the reproducibility of the F.E.V. or the F.V.C. was not affected.

We are much indebted to Dr. J. M. Rogan, Chief Medical Officer of the National Coal Board, for his encouragement and advice in the preparation of this paper.

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